I want to move my body - right now! The CRAVE Scale to measure state motivation for physical activity and sedentary behavior

Matthew A. Stults-Kolehmainen1,2*, Miguel Blacutt2*, Todd A. Gilson3*, Philip R. Stanforth4, Amanda L. Divins, John B. Bartholomew4, Nia Fogelman6, Garrett I. Ash7,8, Joseph T. Ciccolo2, Line Brotnow Decker9,10, Susannah L. Williamson11, Rajita Sinha6

1Bariatric and Minimally Invasive Surgery Program, Yale New Haven Hospital, New Haven, Connecticut, United States of America
2Department of Biobehavioral Sciences, Teachers College, Columbia University, New York, New York, United States of America
3Department of Kinesiology and Physical Education, Northern Illinois University, DeKalb, Illinois, United States of America
4Department of Kinesiology and Health Education, The University of Texas at Austin, Austin, Texas, United States of America
5Department of Health and Human Performance, Northwestern State University, Natchitoches, Louisiana, United States of America
6Yale Stress Center, Yale School of Medicine, New Haven, Connecticut, United States of America
7Pain, Research, Informatics, Medical Comorbidities and Education Center (PRIME), VA Connecticut Healthcare System, West Haven, Connecticut, United States of America
8Center for Medical Informatics, Yale School of Medicine, New Haven, Connecticut, United States of America
9Yale Child Study Center, Yale School of Medicine, New Haven, Connecticut, United States of America
10Department of Psychiatric Research, Akershus University Hospital, Nordbyhagen, Norway
11Department of Health and Kinesiology, Texas A&M University, College Station, Texas, United States of America

* Correspondence:
Matthew Stults-Kolehmainen
Matthew.stults-kolehmainen@ynhh.org

Miguel Blacutt
meb2305@tc.columbia.edu

Todd A. Gilson
tgilson@niu.edu

† These authors share first authorship.

Keywords: urge for movement, desire, sedentary activity, physical activity, scale development, motivation, exercise, factor analysis
Abstract

Energy expenditure undulates throughout the day and likely motivation for it. The aim of this investigation was to create a short assessment (CRAVE) to measure transient wants or desires for physical activity and sedentary behaviors. Five studies were conducted to construct and validate the scale, with 1035 subjects completing the scale a total of 1,697 times. In Study 1, participants (n= 402, M_age = 20.9±3.2) completed a questionnaire inquiring about the “want” or “desire” to perform behaviors “at the present moment”. Seven items related to physical activity (e.g., move my body). Eight items addressed sedentary behaviors (e.g., rest my body).

Exploratory factor analysis revealed that 13 items should be retained, loading onto two factors (rest, move). In Study 2 (n= 444, M_age = 20.3±2.9) a confirmatory factor analysis revealed a good fit for the model (CFI=.99, RMSEA=.049). Items loaded strongly onto two latent factors (> .7). Rest/move were inversely related for both sets of factor analyses (-.75 for both). In Study 3, 127 participants (M_age = 28.1±7.9) completed the CRAVE up to 10 times over a 2-year period. Cronbach alphas were high (> .86). A linear mixed model revealed that test-retest reliability was stronger when the CRAVE was administered twice on the same day (> .73) than compared to retest over 6-month intervals (> .37). In Study 4, a maximal treadmill test was completed by 21 participants (M_age = 20.5±1.4). The CRAVE was completed immediately pre and post, along with other surveys for perceived physical fatigue. Desire to move decreased 35% and rest increased 61%. Changes in perceived physical fatigue correlated with move (r = -.52) and rest (r = .53). In Study 5, 41 university students (M_age = 22.5±5.1) sat quietly during a 50-minute lecture. They completed the CRAVE at 3 times points along with the Activation/Deactivation Checklist. Desire to move increased 15% while rest decreased 15%. Perceived energy, but not tension, was related to both move (r = .38) and rest (r = -.38). In conclusion, the CRAVE scale has good psychometric properties. Future studies need to explore how desires to move and rest relate to dynamic changes in physical activity and sedentarism.
Introduction

Conditions such as obesity, cardiovascular disease (CVD) and diabetes are all related to a lack of muscular movement and minimal energy expenditure (EE) (54). EE, however, is affected by distinct behaviors falling in two dichotomous categories: physical activity (P.A.; i.e., occupational activity, active transit, exercise) and sedentary behavior (e.g., sitting, watching TV, sleep). These are ostensibly separate but not mutually exclusive constructs, which have independent and interacting effects on health (51, 53). Recent evidence indicates that humans display substantial variability in engaging in active and sedentary behaviors. For instance, some individuals achieve high levels of activity but also high levels of sedentarism (80). Given the distinction between PA and inactivity, growing importance is being placed on trying to understand the antecedents or determinants of these two behaviors, from the levels of the environment to the gene (7, 60). Motivation appears to be a key intermediary. Unfortunately, there is a gap in our current understanding of how the environment and the brain interact to actually motivate movement and sedentary behaviors, particularly on a moment to moment basis, which suggests that additional mechanisms may be responsible for their linkage (7).

Research in the area of motivational processes has greatly lagged behind work in the area of cognition and emotion (18), but newer models are reviving older perspectives and synthesizing this with data that suggests that motivated behavior starts with desires and urges (8, 19, 28, 31, 32, 58, 61). Two dual-process models of physical activity have recently emerged: the Affective Reflective Theory of Physical Inactivity and Exercise (12) and the Affect and Health Behavior Framework (87). Both of these models view physical activity and sedentary outcomes as the consequence of interactions between two systems, one responsible for affective processing and one responsible for intentional planning, goal setting and other cognitive processes. Brand and Ekekakis (2018) incorporate Lewin’s (44) ideas of driving forces and restraining forces, the interplay of which results in tensions. In ART, the affective system operates with automatic processes of stimulus conditioning and hedonic value assessment result in an action impulse, which is the antecedent to physically active behavior. They also note that “…core affective valence may have a direct, immediate impact on behavior through behavioral urges” (12). The AHBF model (87) specifies that the faster, affective system operates on behavior through two intermediaries: automatic motivation (i.e., “wanting”, “dread”) and affectively charged motivational states (i.e., “craving & desire”, fear). A total lack of desire is a hallmark of amotivation as outlined in Self-Determination Theory (75). How feelings of urges, wants, desires and cravings relate and differ is currently the subject of another paper in this Special Issue of this journal (Citation intentionally omitted). Unfortunately, these models have not been tested rigorously to understand the strength of the association between desires/urges and physically active behaviors.

Despite the lack of data in this area, there is a preponderance of information about desire for movement in other relevant literatures. Urges to move, especially at night, are a defining characteristic of Restless Leg Syndrome, which may affect other parts of the body as well (20, 37, 63). Urges to move the entire body, particularly for the purpose of energy expenditure are also a key symptom of exercise dependence (24). Long-term use of anti-psychotic medication can result in psychogenic movement disorders, such as tardive dyskinesia and akathisia, the latter of which results in a pressing need to constantly fidget and move about (35). Aside from these clinical presentations, desires to move may manifest in response to environmental conditions, like upbeat rhythmic music. Groove is a state of clearly desiring to move the body in response to a rhythm or harmony (43, 47). Other researchers have identified desires as being specific to fitness, for instance, a desire to gain muscular strength (38) or even to generally engage in sport (30, 32). In some cases, dopamine receptor-blocking agents can induce tardive dyskinesia, which results to an inner urge to move that manifests in chorea, dystonia, akathisia, tics and tremors (79). Even animals clearly demonstrate urges to move when deprived of it, what is known as “appetence” for muscular motion (19). Finally, in ancient philosophy, Aristotle
WANTS / DESIRES FOR PHYSICAL ACTIVITY

concluded, “It is manifest, therefore, that what is called desire is the sort of faculty in the [mind] which initiates movement” (2, 49, 67) Further information about the conceptual basis of desire in physical activity can be found in an article in this same Special Issue (Citation intentionally omitted).

Consequently, modern exercise psychology theories appear to be supported by a variety of scientific and theoretical evidence spanning the course of history.

At this juncture, there is intersecting research strongly suggesting that humans possess wants / desires for movement and rest behaviors (8, 19). However, scientific inquiry to strengthen our understanding of these desires is currently impeded by a lack of validated instrumentation (55). Only single-item surveys of desire for physical activity exist, such as of state motivation for specific exercise tasks, or desires for fitness, all of which lack validation (34, 38). On the other hand, there has been substantial development of instruments to assess desire, wanting and craving for reward substances, foods and behaviors (11, 66, 68, 81) and neurobiological substrates associated with desire and craving states (70).

The aim of the current investigation, therefore, is to create and validate an instrument which could be utilized to measure subjective ratings of desire or want for movement behaviors and sedentary behaviors. Based on previous literature, we hypothesized that: 1) humans have a measurable motivation to move that may be measured as a want or desire (or urge), and, 2) want or desire for movement/physical activity are separable from want / desire to rest or be sedentary (i.e., load on different factors), 3) wants / desires are transitory or possess state-like qualities and can be measured reliably in the current moment, 4) these motivational states will change with the provision of prolonged rest and exercise and 5) a scale to measure desires/wants will have acceptable construct, and more specifically, convergent validity. In regard to hypothesis 2, it could be argued that additional desire/want factors other than move and rest may emerge (e.g., a desire or want for stillness, an outcome of meditation; (83). Consequently, to test these notions two studies were conducted with college-aged populations to psychometrically validate a questionnaire focused on cravings for movement/physical activity and rest/ sedentarity. In the first study, an exploratory factor analysis was conducted, and in the second study a confirmatory factor analysis took place.

Study 1

Introduction

The purpose of study 1 was to construct a scale for desires/wants to move and rest with good structural properties. It addresses the first three of the major hypotheses from above. Considerations are: 1) to align with theoretical models of desire to move / rest, 2) to keep the scale consistent with other validated scales of desire / craving. Study 1 involved the initial development of the scale and was highly structural: we generated items for the scale, administered the items to a test population, analyzed its factor structure and determined an appropriate number of scale items to occupy each dimension – trimming items when appropriate. We aimed to consider the 4 essential properties of desires/cravings in this scale development: 1) desires for movement and rest reside on different dimensions as in contrast to opposite sides of the same pole, 2) they might be described as “wants” or simply “desires”, 3) desires vary in intensity, and may be completely absent (have a 0 point), 4) desires/wants have state-like traits; they are “in the present moment”.

Methods

Participants. A total of 402 college students from a public Midwestern university participated in the first study (M_age = 20.9 years, SD = 3.2). Self-reported gender data revealed that 61.6% of participants were male; whereas ethnicity data showed that 64.9% of the students classified themselves as Caucasian, 17.7% as African-American, 6% as Hispanic/Latino(a), 5% as Asian American, 4.7% as multiple ethnicities, and 1.5% as other/not listed. The academic rank of students was evenly distributed and ranged from a low of 23.1% for sophomores to 26.6% for seniors. Finally, most students (95%) were not athletes on varsity teams sponsored by
the university. All individuals signed an informed consent. The study was approved by the Institutional Review Board at Northern Illinois University, in accordance with the Declaration of Helsinki, protocol # HS13-0035.

**Instrumentation.** In addition to a demographic questionnaire, participants completed the Cravings for Rest and Volitional Energy Expenditure (CRAVE) consisting of 30 questions related to the urges/wanting or desire individuals had to perform various behaviors or activities. The questionnaire was further divided into two identical 15 question sections; the first of which asked participants to respond based on their want/desire to behave in the manners listed over the past week (WEEK), while the second was focused on individuals’ want/desire to perform the behaviors at this very moment ("Right now") (NOW) (26, 77). Questionnaire items for each section of CRAVE were developed by two researchers who have research experience in the areas of physical activity, kinesiology, and psychology of addictive behaviors – and were then checked for face validity by three other scholars (noted for being experts in the field of exercise psychology) from three different institutions. Inventory items were characterized by their dichotomous nature, in that seven items related to being physically active (e.g., want/desire to burn some calories; be physically active; exert my muscles, etc.) and eight items were sedentary behaviors (e.g., want/desire to just sit down, do nothing active, rest my body, etc.). Participants responded to each item on an 11-point Likert Scale ranging from 0 = not at all, to 10 = more than ever (36).

**Procedure.** After receiving IRB approval, two researchers from the byline reached out to professors at the selected university who instructed classes of more than 50 students (either by e-mail or phone) soliciting participation by briefly describing the nature of the present study and the approximately 10-minute time commitment required. Seven professors agreed to the request and upon the prearranged date/time one author traveled to each class for data collection. When addressing the students, the researcher explained the purpose/goals of the study, participants’ rights if they elected to participate, and that all data were anonymous (e.g, no names collected). Students were then allowed time to ask any questions or opt out of participation (no student declined participation). Questionnaires were distributed by the researcher and these were completed at the beginning of each class. After completion, these were gathered by the same individual.

**Data Analysis.** Data were double-entered and cleaned and then screened for univariate outliers. In order to test the hypothesized 2-factor structure of the REST and MOVE items, exploratory factor analysis (EFA) was conducted to examine the salient number of factors. First, tests of assumptions were conducted (KMO and Bartlett’s test for sphericity) to determine interrelations of items and factorability of data. Next, we determined to select a factor extraction method (i.e., maximum likelihood, principal axis) based on normality of data (15). The number of factors retained was specified by examining the scree plot and by using the Kaiser criterion (retaining all factors with Eigenvalues > 1.0) (15). It was decided a priori to use an oblique rotation (promax), which allows factors to correlate amongst each other, providing a more inclusive interpretation of the data (64). Factor loadings were examined with the criterion that a valid factor would have at least five items with loadings greater than .5 (15).

**Results.** Cases with missing data on any variables were dropped from further analyses, yielding a final sample size of 402 (26.8 cases per item in each analysis). Means (SD) for NOW items ranged from 3.14 (3.05) for “veg out” (vegetate) to 5.81 (2.87) for “move around”. For WEEK, they ranged from 2.77 (2.49) for “be motionless” to 7.33 (2.18) for “be physically active”. NOW and WEEK items (i.e., want to “move my body right now versus in the past week) were correlated (r values=.30 to .61).

Initial tests of assumptions supported the factorability of the data for both Right now (NOW), KMO = .95, Bartlett’s $\chi^2$(105) = 4887, p<.001, and Past week (WEEK) items, KMO = .89, Bartlett’s $\chi^2$(105) = 3133, p<.001. In addition, 95.1% of correlations (r) between items for NOW were above .3. For WEEK, this was 64%. Given these initial analyses, EFA was conducted on all items for both NOW and WEEK.

Data were normally distributed; therefore, maximum likelihood (ML) analysis was conducted with promax rotation. Based on scree plots and Kaiser’s criterion, NOW had two factors, both with Eigenvalues above 1.0 (8.82 and 1.38, respectively). This explained 63.2% of the total variance when extracted. For NOW, factor 1 (named “Move”) contained 7 items with loadings all above .54. Factor 2 (named “Rest”) contained 8 items with loadings all above .57. However, for WEEK, there were 3 factors (Eigenvalues = 6.02, 2.42, 1.28).
explaining 56.3% of the variance after extraction. Factor 1 was similar to that for NOW (with the loading for item “move about” dropping to .40). The additional two factors separated the items for rest (factors 2 and 3 received 6 and 2 items, respectively).

Communalities for all NOW items were >.57 with the exception of “veg out” (vegetate), which was .23 and “walk about”, which was .28. These communalities were also poor for WEEK (.17 and .15, respectively). All other communalities for WEEK were above .40, which is considered acceptable (15). “Veg out” (vegetate) and “walk about” had the smallest loadings with their respective factors as determined from the structure matrix (.47 and .53). Therefore, these two items were eliminated from the scale.

Re-running the EFA with just 13 items resulted in 2 factors for both NOW and WEEK, explaining 69% and 56.4% of the variance after extraction, respectively, with all loadings >.6. [see Additional file 1 for the final scale]. Correlations between Move and Rest factors were -.75 and -.49 for NOW and WEEK, respectively. Thus, the factor loading matrix for this final solution for NOW and WEEK is presented in Table 1. With the shortened version of the CRAVE, estimates of internal consistency (Chronbach’s Alpha) demonstrated there was good reliability of the subscales: .93 (move – now), .82 (move- past week), .89 (rest – now) and .87 (rest – past week).
In Study 1, a scale to measure wants/desires for movement and rest was created with 15 items and was later completed by over 400 participants. Results from this investigation supported all applicable hypotheses. Participants rated their desires to move and rest and being greater than 0 – in other words, they perceived these desires existed. As anticipated, items separated into two distinct factors – named move (6 items) and rest (7 items). Move and rest factors were moderately and inversely related. Reliability of the subscales was high, particularly when assessed “right now”. Overall, these results indicate that the scale has good initial psychometric properties and further evaluation and validity testing is appropriate.

### Study 2

#### Introduction

With structural considerations of the scale established, the purpose of study 2 was to confirm the structure as a model. Specifically, Study 2 directly tests hypotheses 1-3 and indirectly 4. A further objective was

#### Table 1  Factor loadings (FL) and communalities for Right now (NOW) and Past Week (Week) versions of CRAVE

| Item # | FL (Move) | FL (Rest) | Communality |
|--------|-----------|-----------|-------------|
| 1      | .803      | .740      |             |
| 2      | .885      | .844      |             |
| 3      | .778      | .569      |             |
| 4      | .871      | .788      |             |
| 5      | .867      | .747      |             |
| 6      | .704      | .705      |             |
| 7      | .681      | .654      |             |
| 8      | .689      | .702      |             |
| 9      | .758      | .745      |             |
| 10     | .737      | .604      |             |
| 11     | .907      | .712      |             |
| 12     | .752      | .549      |             |
| 13     | .767      | .609      |             |
| 14     | .767      | .609      |             |

**NOW**

| Item # | FL (Move) | FL (Rest) | Communality |
|--------|-----------|-----------|-------------|
| 1      | .734      | .564      |             |
| 2      | .907      | .795      |             |
| 3      | .620      | .348      |             |
| 4      | .714      | .523      |             |
| 5      | .781      | .609      |             |
| 6      | .698      | .473      |             |

**WEEK**

| Item # | FL (Move) | FL (Rest) | Communality |
|--------|-----------|-----------|-------------|
| 3      | .645      | .575      |             |
| 4      | .740      | .572      |             |
| 5      | .655      | .533      |             |
| 6      | .764      | .649      |             |
| 7      | .682      | .368      |             |
| 8      | .844      | .595      |             |
| 9      | .813      | .520      |             |

1."Veg out (Vegetate)" and “Walk about” were removed from the final analysis leaving 13 items for the final scale (see text).

#### Discussion

In Study 1, a scale to measure wants/desires for movement and rest was created with 15 items and was later completed by over 400 participants. Results from this investigation supported all applicable hypotheses. Participants rated their desires to move and rest and being greater than 0 – in other words, they perceived these desires existed. As anticipated, items separated into two distinct factors – named move (6 items) and rest (7 items). Move and rest factors were moderately and inversely related. Reliability of the subscales was high, particularly when assessed “right now”. Overall, these results indicate that the scale has good initial psychometric properties and further evaluation and validity testing is appropriate.
to determine if there were any issues with discriminate validity (i.e., too much overlap between move and rest factors). As part of hypothesis 3, an aim was to assess the reliability of the scale. Secondary purposes of Study 2 were to explore how it varies by demographics (gender, race/ethnicity, age) and determine if there is an association of move/rest desires with a simple measure of exercise habit.

**Methods**

**Participants.** In the second study, a total of 444 college students ($M_{age} = 20.3$ years, $SD = 2.9$) from a public Midwestern university participated. There was no overlap between studies for subjects. Self-report data from the demographic questionnaire highlighted the fact that 59.2% of the participants were female, 39.4% male, and 1.4% elected not to respond. The ethnic make-up of the sample was quite diverse; as specifically, 47.5% of the students classified themselves as Caucasian, 28.1% as African-American, 8.4% as Hispanic/Latino(a), 7% as Asian American, 0.7% as Native American, 7.4% as multiple ethnicities, and 0.9% as other/not listed. Student academic rank resembled a positive skewness, with freshman accounting for 28.7% of the sample, sophomores = 29.2%, juniors = 29.8%, seniors = 11.8%, and graduate students = 0.4%. Equivalent to Study 1, 95% of participants were not involved in varsity sports at the university; however, using the stages of change from the Transtheoretical Model to assess exercise engagement, 79.1% of students in the current study either exercised somewhat, exercised regularly for less than six months, or exercised regularly for more than six months. Finally, Body Mass Index (BMI) was also calculated, revealing that the second sample had a BMI of 25.0 ($SD = 5.2$). All individuals signed an informed consent. The study was approved by the Institutional Review Board at Northern Illinois University, in accordance with the Declaration of Helsinki, protocol # HS13-0035.

**Instrumentation.** Similar to Study 1, participants completed a demographic questionnaire – with the only difference being the inclusion of three demographic questions addressing the Transtheoretical model (TTM) stages of change related to exercise involvement and height and weight to calculate BMI (46). Students then responded to the identical CRAVE questions used in Study 1.

**Procedure.** Following the procedures employed in the previous study, two researchers again contacted professors at the predetermined university who had enrollments of greater than 50 students in a class. Important to note is that Study 2 was conducted in the semester immediately following data collection for Study 1; thus, researchers were careful to exclude potentially large classes based on course sequencing to exclude the possibility of recurring participants.) Eight professors agreed to the request for class participation and upon the rearranged date/time one researcher from the byline traveled to each class for data collection. Once again, the researcher explained the nature of the study, the anonymity of responses, allowed time for questions or for students to opt out of participation (no student declined participation), distributed the questionnaires for completion before class, and collected them upon completion.

**Data Analysis.** Reliability (internal consistency) was tested with Cronbach’s Alpha. To test the relative fit of the CRAVE, confirmatory factor analysis (CFA) was used with the AMOS 21 software package (IBM, Chicago, IL.). To adequately test each proposed model a chi-square ($\chi^2$) test, goodness of fit index (GFI), adjusted goodness of fit index (AGFI), comparative fit index (CFI), root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR) were employed. These indices have been shown to be the most important when determining whether to support or reject hypotheses with CFA (41). To investigate the association between desire for energy expenditure as assessed by the CRAVE scale and TTM stages of change for exercise a one-way ANOVA and regression analyses were conducted. Stage of change was modeled as a continuous variable. In these analyses, the average across CRAVE subscale items was used as the dependent variable.

**Results**

Of 444 participants, 426 people were included in the final analysis due to listwise deletion of participants lacking full data. Means (SD) for NOW items ranged from 3.06 (3.06) for “veg out” to 6.00 (3.31) for “rest my body” For WEEK, they ranged from 2.29 (2.38) for “be motionless” to 7.55 (2.09) for “be physically active”. NOW and WEEK items (i.e., want to “move my body” right now versus in the past week)
were correlated (r’s=.30 to .64, p<.001). The CRAVE demonstrated good internal consistency. Reliability (Cronbach’s Alpha) was .92 (move – now), .85 (move- past week), .90 (rest – now) and .82 (rest – past week).

Based on the EFA analysis, the CFA was run with 13 items. All latent factors loaded strongly onto their respective items (> .7 for NOW and >.5 for WEEK). See Figure 1 for the NOW model. The correlation between Rest-Move factors was inverse and moderate to strong (r=-.75 and r=-.53 for the NOW and WEEK scales, respectively) but not so strong as to suggest a significant discriminant validity issue (where r>.85).

The selected model fit indices all reached appropriate levels, suggesting an adequate fit of the present 2-factor model to the data (33, 41). See Table 2. It is important to note that the significant χ² result is expected due to the large sample size (41). Each of the four subscales showed adequate internal consistency (all Cronbach’s α >.86).

Analyses conducted to determine the association between CRAVE constructs (13-item scale) and TTM stages of change suggest statistically significant differences in desire to move and rest according to exercise stage of change, F(4, 424) = 4.03-14.28, p values < .003, η² values = .037-.10. To further probe the association, linear regression analysis revealed that stage of change predicted 6.5% of variance in desire to rest, β = -.26, t(424) = -5.41, p < .001, and 8.3% of variance in desire to move for NOW, β = .26, t(424) = 5.57, p < .001. Similarly for WEEK, it predicted 3% of variance in desire to rest, β = -.17, t(424) = -3.63, p < .001, and 11.2% of variance in desire to move, β = .31, t(424) = 6.80, p < .001. BMI did not predict any CRAVE subscale. Move NOW, F(1, 420) = 3.75, p = .053, η² = .01, and rest NOW, F(1, 420) = 3.68, p = .056, η² = .01, did not vary by gender (nor did WEEK). However, age did predict rest for NOW, β = -.19, t(424) = -3.89, p < .001, R² = .04, but not movement NOW, β = .09, t(424) = -1.83, p = .068, nor rest or movement for WEEK.

| Model       | χ²    | GFI  | AGFI | CFI  | NFI  | RMSEA | SRMR |
|-------------|-------|------|------|------|------|-------|------|
| Now         | 123.80* | .95  | .94  | .99  | .97  | .049  | .022 |
| Week        | 179.30* | .94  | .91  | .96  | .94  | .067  | .044 |

*Note.* GFI = Goodness of Fit Index, AGFI = Adjusted Goodness of Fit Index, CFI = Comparative Fit Index, NFI = Normed Fit Index, RMSEA = Root Mean Square Error of Approximation, SRMR = Standardized Root Mean Square Residuals.

*p < .01.
To further assess the psychometric properties of the CRAVE, 400+ new participants were administered the refined 13-item version of the scale. Hypotheses specific to this study were all supported. Participants rated their desires for movement and rest as greater than 0; in other words, they sensed that such desires existed. A confirmatory factor analysis supported the current model structure and move/rest factors were moderately and inversely related. Problems with discriminate validity were
not detected. Furthermore, reliability (internal consistency) of the subscales was good. The transtheoretical model (TTM) construct of stage-of-change for exercise predicted CRAVE subscales, explaining 8.3% and 6.5% of the variance in desires to move and rest (NOW), respectively. Other factors like BMI and gender did not predict CRAVE factors, but older age predicted less desire for rest. Results from Study 2 provide further evidence that the CRAVE has good psychometric properties and may be moved forward for further validity testing.

Study 3

Introduction

The purpose of Study 3 was to investigate the reliability and internal consistency of the Move and Rest subscales of the CRAVE tool throughout a 2-year time span, as well as within the same day. Study 3 directly tested hypothesis 1-3 and 5. We hypothesized that the desire to move and rest scores would show greater reliability within the same day than across 2-years. These findings would suggest that that the desire to move or rest has state-like properties rather than trait like properties. States can be defined as brief, temporary and easily influenced by changes in the external environment or internal milieu. Meanwhile, traits are stable, long-lasting and primarily emanate from within the person (14).

Methods

The CRAVE Scale was administered to 127 subjects (28.1±7.9, 57% non-Caucasian, 47% female) at 0, 6, 12, 18 and 24-months and at two time points (Point 1; Point 2) within the same testing session. CRAVE scores were collected before and after they completed a battery of self-report and structured interviews that were part of a larger study aimed at understanding the motivation to eat hyperpalatable foods (71). Statistical tests were performed using RStudio (Version 1.2.1335; R Foundation for Statistical Computing, Vienna, AT). Participants completed the CRAVE a variable number of times. Therefore, within subjects test-retest reliability was assessed with an intra-class correlation index generated with a random intercept model using the CorrMixed package (84). Test-retest reliability was assessed for within session (i.e. at the beginning and end of the testing session) and between sessions (i.e. at timepoints 0, 6, 12, 18, and 24 months) for Move and Rest subscores. Internal consistency was evaluated with Cronbach’s Alpha. A secondary aim was to determine if CRAVE scores varied by gender by examining interactions in the LME. The study was approved by the Human Investigation Committee at the Yale School of Medicine, in accordance with the Declaration of Helsinki.

Results

Table 3. Means, standard deviations and correlations for Move and Rest Scores within the same test day (session points 1 and 2) across two years of follow up

| Time (months) | Move (Point 1) | Move (Point 2) | Move Scores (r) | Rest (Point 1) | Rest (Point 2) | Rest Scores (r) |
|---------------|----------------|----------------|-----------------|----------------|----------------|----------------|
| 0             | 32.7 ± 15.2    | 35.9 ± 12.8    | 0.95            | 25.1 ± 13.9    | 20.9 ± 11.9    | 0.89           |
| 6             | 28.4 ± 12.9    | 26.7 ± 14.5    | 0.74            | 24.3 ± 14.2    | 24.3 ± 16.7    | 0.73           |
| 12            | 30.6 ± 13.7    | 28.8 ± 13.6    | 0.79            | 24.4 ± 14.6    | 23.9 ± 15.8    | 0.82           |
| 18            | 29.0 ± 13.0    | 29.4 ± 13.1    | 0.86            | 28.0 ± 15.9    | 24.5 ± 15.2    | 0.76           |
| 24            | 29.9 ± 11.6    | 28.0 ± 11.7    | 0.82            | 26.4 ± 16.0    | 25.4 ± 16.3    | 0.84           |

Participants completed the CRAVE, on average 5.4 (±3.04) times over 24 months. The CRAVE Scale showed greater test-retest reliability within each day than across 0, 6, 12, 18 and 24-months, as shown by Table
3. Strong correlations for found for within-day Move Scores correlations (r’s = .75-.95, p < .05) and Rest Score correlations (r’s = .73-.89, p < .05). Moderate correlations were found for Move scores across 0-24 months at Point 1 (r = .49, p < .05 ) and Point 2 (r = .40, p < .05) for point 2 (p-values < .05). Further, moderate correlations were found for Rest Scores across 0-24months at Point 1 (r= .37, p < .05) and Point 2 (r = .37, p <.05)

Chronbach alpha tests at 0, 6, 12, 18 and 24 months were found to be 0.94-0.96 for Move at Point 1, 0.93-0.96 for Move at Point 2, 0.90-0.95 for Rest at Point 1, and 0.86-0.96 for Rest at Point2. No gender x time interactions were observed in the model.

**Discussion**

The results from Study 3 support the first hypothesis, which is that desires to move and rest have greater reliability within the same day than across 2-years. This was demonstrated by significantly greater associations between the urge to move and rest at two points within the same day compared to associations between these desires across multiple months. These findings suggest that the desire to move and rest have state-like properties rather than trait-like properties and are congruent with previous literature demonstrating that the desire to be physically active is not stable and can be affected by a myriad of factors, such as depression, mood, affect, anxiety, anger and stress (76). In accordance with this, Rowland (1998) has proposed that the desire to perform physical activity can be affected by factors such as personal desires, peer influences, and environmental conditions (62). Further, the results of Experiment 3 show that Move and Rest subscores have strong internal consistency, as demonstrated by high Chronbach alpha scores at each time the CRAVE was measured. A strength of this study is that it included 686 observations of the CRAVE scale, measured in 125 participants over 2 years.

**Study 4**

**Introduction**

The purpose of Study 4 was to investigate changes in the desire to move and rest after a bout of maximal exercise. In addition, the hallmark of any urge or craving is change, sometimes rapidly. Study 4 directly tested hypothesis 3 and 4, and indirectly tested hypothesis 1 and 2. In particular, there is typically a reduction in desire once a sufficient quantity or intensity of a relevant stimulus is experienced, in other words, satiation is reached (57). Conversely, during deprivation, desires will increase. At sufficiently high levels of either satiation or deprivation, the experience will be tension. The same should hold true for desires for movement and rest. A maximal treadmill test provides an opportunity for both an excess of movement and the physiological deprivation of rest. We hypothesize that a bout of maximal exercise will satiate the desire to move and obviously deprive the body of respite, thereby leading to reductions in the desire to move and increases in the desire to rest (Hypothesis 4). We also hypothesize that these feelings will be related to, but distinct from sensation of physical and mental energy and fatigue (in accordance with Hypothesis 5).

**Methods**

Study 4 included twenty-one students (M_age = 20.5±1.4; 58% female) who identified themselves as 42.9% Caucasian, 19% Asian/Pacific Islander, 19% Hispanic, 14.3% multiple races and 4.8% Arab. The students were mainly undergraduates participating in physical activity classes at The University of Texas at Austin (Austin, TX, USA). The study was approved by the University of Texas at Austin’s Institutional Review Board and informed consent was obtained from all participants.

Participants were advised to refrain from exercise for 48 hours prior to the laboratory testing session. During the testing session, participants underwent a maximal, graded treadmill test that was developed for this population of college students. In this protocol, the grade or speed of the exercise was increased every minute for the first 10 minutes and then speed only was increased every minute until participants reached volitional fatigue. Once volitional fatigue was reached, speed and grade were reduced to provide the participant with a 5-minute cooldown walk.
The speed of CRAVE, physical energy, physical fatigue, mental energy and mental fatigue were measured one minute prior to starting the treadmill test, as well as two minutes after completing the test. Physical and mental fatigue and energy were measured pre- and post-exercise using Visual Analogue Scales developed and validated by O’Connor (27, 50). Respondents placed a mark on a standard 10-cm line. Examples of anchors include, “I have no energy” to “Strongest feelings of energy ever felt”. Statistical tests were conducted using SPSS (Version 25; IBM SPSS Statistics Software, Chicago, IL, USA). Paired t-tests were used to compare pre- and post-CRAVE scores. Pearson’s correlations were used to assess relationships between all CRAVE scores, mental fatigue, mental energy, physical fatigue, and physical energy.

Results

Figure 2. Desire to move and rest pre and post-treadmill exercise test
† Indicates significant difference from pre- to post-exercise test (p < .05)
should examine changes in the desire to move and rest with a more ecologically valid exercise protocol, in a

Figure 3. Pearson correlation matrix between pre- and post-treadmill test move and rest scores, physical energy, physical fatigue, mental energy and mental fatigue scores, and change in those scores. * denotes $p < .05$; ** denotes $p < .01$; *** denotes $p < .001$

On average, participants took $13.5 \pm 2.0$ min to reach volitional fatigue on the treadmill test, reached a maximum heart rate of $194.7 \pm 10$ bpm and reported a Rating of Perceived Exertion (RPE, Borg Scale) of $18.3 \pm 1.0$. Desire to move significantly decreased from pre- to post-treadmill test ($39.9 \pm 9.6$ vs. $29.5 \pm 10.7$, $p < 0.01$), as shown in Figure 2. Conversely, desire to rest significantly increased from pre- to post-treadmill test ($17.8 \pm 12.3$ vs. $29.1 \pm 18.1$, $p < 0.01$), as shown in Figure 2. Baseline desire to move was significantly associated with desire to move post-treadmill ($r = 0.63$, $p = .002$). Baseline desire to rest was significantly associated with the change in move ($r = 0.53$, $p = .014$) and change in rest ($r = -.48$, $p = .027$). In addition, change in desire to move was inversely associated with change in desire to rest ($r = -.73$, $p = .002$).

Figure 3 shows the results of all correlation tests conducted. Baseline desire to move was significantly associated with the post-treadmill test physical energy score ($r = .45$, $p = .041$). Change in desire to move had a negative association with change in physical fatigue ($r = -.52$, $p = .019$) but not with change in physical energy ($r = .31$), mental energy ($r = -.10$) or mental fatigue ($r = -.17$). Change in rest had a significant inverse correlation with change in physical energy ($r = -.64$, $p = .003$) and a positive correlation with change in physical fatigue ($r = .53$, $p = .016$). However, it was not correlated with change in either mental energy or fatigue.

Discussion

It was shown that desires to move and rest change with a maximal exercise stimulus. In support of the hypothesis, it was found that a bout of exercise satiates the desire to move and places the body in a state of physiological deprivation for rest. This was demonstrated with a decrease in desire to move and an increase in desire to rest from pre- to post-treadmill test. Further, these findings show that perceived physical fatigue has a positive association with the desire to rest, and an inverse association with the desire to move. Additionally, perceived physical energy had a negative association with the desire to rest. These findings provide convergent validity of the scale. They also support the use of the CRAVE Scale as a tool that is sensitive to changes in the desire to move and rest before and after exercise. A limitation to this study is that it is not known whether participants honored the request to refrain from exercise for 48 hours, therefore it is unknown if the desire to move was sufficiently built up during this time. Also, the current study did not assess positive and negative affect – other factors that likely relate to desires to move but not strongly (87). In a future study, researchers should examine changes in the desire to move and rest with a more ecologically valid exercise protocol, in a
real-life exercise setting such as a full resistance training workout, sports game, or a 2-mile run, etc. Future studies should also track recovery of desires for a sufficient period after they have been altered (e.g., over 30 minutes – 2 hours or more).

**Study 5**

**Introduction**

In Study 4, we investigated changes in the desire to move or rest in response to a bout of maximal exercise. In contrast, the purpose of Experiment 5 was to assess changes in the desires to move or rest in response to sedentary behavior. Study 5 directly tested hypothesis 3 and 4, and indirectly tested hypothesis 1 and 2. Desires to move and rest should vary by deprivation or satiation of these feelings (57). Consequently, restricting movement, particularly in a group of individuals more likely to move (young adults) should result in increased desires to move. Conversely, satiating the need to rest through sedentary behavior should result in lesser of these desires. As the sedentary behavior is prolonged, the desire to move will build up and be felt as a type of tension, perhaps analogous to appetite (19, 45, 62). Based on these premises, we hypothesize that prolonged sitting during a university lecture period would increase the desire to move and decrease the desire to rest (Hypothesis 4). It is also proposed that desire to move/rest will be related to, but distinct from, perceptions of energy, fatigue, tension and calmness (in accordance with Hypothesis 5). A final aim was to determine the internal consistency and test-retest reliability of the CRAVE scale (supporting Hypothesis 3).

**Methods**

The CRAVE Scale and Thayer Activation-Deactivation (AD) Checklist (78) were administered to 41 students (mean age 22.5±5.1 years; 26.8% non-Caucasian; 24.4% female) before, during and at the end of a 50-minute lecture. Students quietly sat, listened and took notes while the instructor delivered a PowerPoint presentation. The AD Checklist consists of 20 items answered on a 1-10 Likert Scale and measures perceived energy, tiredness, tension and calmness; this measure was only assessed pre-lecture. Lectures were at either 9AM, 12PM or 3PM. Statistical tests were conducted using RStudio (Version 1.2.1335; R Foundation for Statistical Computing, Vienna, AT) and SPSS (Version 25; IBM SPSS Statistics Software, Chicago, IL, USA). A linear mixed effects model was used to compare pre- and post-lecture CRAVE Scores. Correlations were calculated to evaluate CRAVE and AD Checklist relationships. A one-way ANOVA was used to assess changes in both CRAVE and AD Checklist scores over time. Reliability indices were assessed with Cronbach’s Alpha and inter-class correlations. The study was approved by the Institutional Review Board at Western Illinois University, in accordance with the Declaration of Helsinki.

**Results**

![Graph showing changes in CRAVE scores over time for desire to move and rest.](https://example.com/graph.png)
Figure 3. Desire to move and rest pre-, mid- and post-lecture
† Indicates significant difference from pre-lecture (p < .05)
‡ Indicates significant difference from mid-lecture (p < .05)

It was found that the desire to move was significantly higher post-lecture compared to pre-lecture (32.2±2.0 vs. 27.5±2.0, p = 0.007) and higher than mid-lecture (28.5±2.0, p = .034), as shown in Figure 4. On the other hand, the desire to rest was significantly lower post-lecture compared to pre-lecture (32.3±2.8, p = .016) and lower than mid-lecture (33.1±2.8, p = .019), as shown in Figure 2. Cronbach alpha coefficients were calculated for pre-, mid- and post-lecture, which were found to be 0.90, 0.94, 0.93 for the desire to move, respectively, and 0.89, 0.94, 0.93 for the desire to rest, respectively. Inter-class correlations were calculated for the desire to move (ICC = .85) and the desire to rest (ICC = .90).

Figure 5. Pearson correlation matrix between pre, mid-, and post-lecture move and rest scores, energy, tiredness, tension, calmness, total activation and total deactivation
* denotes p < .05; ** denotes p < .01; *** denotes p < .001

The desire to move pre- and mid-lecture were similar at different times of the day. The post-class desire was significantly higher at 3PM compared to 9AM (44.0±16.6 vs. 28.11±12.2, p = .019). There were no differences in desire to rest based on time of day. Desire to move at baseline was significantly associated with energy (r = .38, p = .018) and calmness (r = -0.47, p = .003), as shown by the correlation matrix in Figure 5. Desire to rest at baseline was significantly associated with energy (r = -0.38, p = 0.026) and tiredness (r = 0.48, p = 0.003). Tension was unrelated to either move or rest.

Discussion
It was found that the desires to move and rest change throughout the course of a period of sedentary behavior. In support of our hypothesis, it was found that prolonged sitting during a university lecture increased the desire to move and decreased the desire to rest. Moreover, these findings show that the CRAVE Scale is a tool that is sensitive to changes in the desire to move and rest before and after sedentary behavior, providing support for the construct validity of this instrument. The CRAVE also demonstrated good reliability. A strength of this investigation was that the observation periods were standardized across the sedentary period (pre-, mid- and post-lecture), and the data was collected at multiple times during the day. However, students did not return to be observed at multiple hours of the day; therefore, within-subject difference at each time of day could not be assessed. Moreover, no data was collected in the evening or at awakening. Consequently, this methodology is limited in the extent to which it can ascertain the influence time of day has on changes in the desire to move or rest.
General Discussion

The main objective of the current investigation was to create and validate an instrument to measure urges and desire (wants) for movement and rest. An exploratory factor analysis revealed that a two-factor solution for movement (6 items) and rest (7 items) desires produced the best fit. These two factors were moderately to strongly correlated, suggesting that factors were related but not completely overlapping. Moreover, a confirmatory factor analysis performed on a separate sample confirmed these findings. Results for Right Now (NOW) and Past Week (WEEK) scales were related but produced slightly different estimates, indicating that this instrument captures a construct that likely has state-like properties. The state-like nature of the CRAVE was later evidenced by the fact that the scale was more closely correlated when observations were separated by just a few hours, compared to intervals of 6 months or more. This data also served to demonstrate the reliability of the CRAVE subscales, which was high for both studies. The CRAVE did not change much with a period of sitting and listening; conversely, the CRAVE was sensitive to change when participants partook in a maximal treadmill test. Wants/desires for rest greatly increased and desires for movement decreased.

The current data indicate that desires for movement and rest likely fall on two different, but related factors. In other words, the desire for movement is not simply the lack of desire for rest, or sedentary behavior, which would imply that the two desires are opposite poles on the same dimension. A two-factor distinction mirrors current thinking about physical activity and sedentarism, as introduced above (51, 53). Similarly, it may be possible that one has high desire for both rest and movement simultaneously, or low desire for both as well. Being high on desire for movement does not necessitate a low level of desire for rest; as in fact, the two may be in conflict. From a neurological perspective, regulation of impulses in the brain for EE and sedentary behavior appears to fall on two distinct corticostriatal pathways, which Beeler and colleagues call “Go” and “No Go” (8). Brain systems responsible for sensations of reward and sensations of pain regulate both aversion to movement and/or “craving” for PA, and these differ from systems responsible for desire for rest (7). This is parsimonious with a vast literature base describing function of the sympathetic and parasympathetic nervous systems (56). Thus, desires for EE and rest likely operate dichotomously and independently, similarly to the dual system models proposed for energy and fatigue (50), activation/deactivation (79) and positive and negative affect (85).

Desires, by definition, have state-like qualities (52), and this appears to be true for desires for movement and rest. Unfortunately, the current study was not designed to investigate fluctuations in desires across time, which would have been a stronger test of our hypothesis that movement and rest desires capture a motivational state. However, NOW and WEEK versions of the CRAVE subscales did confirm that these versions were related but distinctly different. This suggests that participants were able to differentiate their urge/desires at the present moment versus their typical desires over a much longer period of time. As a state, one might surmise that movement and rest desires vary similarly to state measures of affect (i.e., arousal, energy and fatigue). Future research should aim to understand how desires to move and rest relate to and differentiate from arousal, energy, fatigue and other components of affect, providing evidence of construct validity. Likewise, it should be determined how these factors change over time. It is possible that desires / wants for rest and movement may fluctuate diurnally and may further undulate with feedings, sleep, and physical activity (79). It would be useful to observe changes in these constructs before and after an acute bout of exercise, and to determine what other factors affect movement desires, such as environmental cues (e.g., lighting, music), social interactions, et cetera (52).

On the other hand, one might construe that urge and desires for activity and sedentary behaviors are stable and/or may be highly influenced by intra-individual traits. Substantial individual differences have been noted not only in physical activity, movement and non-exercise activity thermogenesis
(NEAT) (42) but also in the acute averse and rewarding effects of physical activity (7). Such a trait would possess a strength that is normally distributed throughout the population and expressed most strongly in young age (21). Some children demonstrate more active temperaments, kinetic personalities (i.e., hyperactivity), or a predilection for physical activity while others are ostensibly more lethargic (25), traits that may persist into adulthood (1, 88).

Regulation of urges and desire for movement and rest are not well understood. However, individual variation is predicted by differences in brain structure and activation and is greatly influenced by genetics (21), which exerts wide influence on processes related to rewards and pain sensation (16). Those who “crave activity” likely have rewards systems that activate in response to physical activity and exercise (7, 16). The neurotransmitter dopamine is implicated in systems responsible for reward and locomotion in the nucleus accumbens and other parts of the brain (9, 48, 65). Evidence from rodent models conclude that the frequency and vigor of locomotion is triggered by affect related motivations (e.g., hunger, reproduction) and more generally caused by changes in internal arousal, which is regulated by the dorsal striatum, forming the input nuclei of the basal ganglia (23, 55, 59). One prime candidate is nescent helix-loop-helix 2 (NHLH2), who’s activity in the brain may regulate motivation to exercise through melanocortin signaling or A-endorphin processing (22). Other candidates could include the dopamine 2 receptor (DRD2) and GABRG3 genes (16). While regions of the brain associated with movement have been partially mapped, no evidence has been found for neural circuitry associated with fear or dread of movement (for a review, see (6)). This points to a limitation within the current study. We aimed to assess and model desires/wants for movement but not dread or aversion for movement as highlighted by the AHBF(87) and further conceptualized in an article published in this Special Issue of the journal (Citation intentionally omitted).

To understand these processes, future studies should aim to assess movement and rest desires in a variety of populations. The current study was limited to young adults completing undergraduate education. Ekkekakis’ (17) synopsis of literature from the mid-to-late 1800s (3-5) submits that while desire is especially strong for the young and those well-trained, it declines with age and deconditioning. One might expect that training status and habituation to physical activity would have an impact on desires for movement. For instance, sedentary and low-active individuals are more likely to experience displeasure during exercise even when it’s low intensity (86). Furthermore, regular exercisers experience greater improvements in mood than non-exercisers (29) and highly active individuals report that enjoyment is the primary motive of exercise (74). Indeed, in the current analysis TTM stage-of-change for exercise did predict desires, explaining a significant amount of variance in the current data. However, it would be useful to determine whether those with higher movement desires actually have more EE from exercise or non-exercise sources (e.g., NEAT, SPA) (42) and whether these change over time with chronic training. Movement desires, or what has been termed “appetence”, is magnified with exercise addiction and anorexia (19). Conversely, the desire to move may decrease with burnout and overtraining, which have depression-like symptoms. Movement and rest wants / desires likely are altered by conditions like acute and chronic illness (72), depression (psychomotor retardation(13), and distress (psychomotor agitation) (40), which may modify incentive salience for movement (10, 59, 61).

As early as 1896, Stedman noted that with nervous and mental disease “the natural conscious craving for exercise is lost” (73). Thus, it is likely but speculative that desires vary over time and across populations, situations and conditions.

Future research should also address how these desires actually motivate and spur behaviors. Desires vary in magnitude, focal attention and their effect on working memory, which results in differential implications for a wide swath of behaviors (61). Intense desires, manifested as psychophysiological cravings and urges, strongly predict future behavior, such as overeating, binging on alcohol, overconsumption of caffeine, excessive engagement in sexual activity, smoking of cigarettes and other behaviors (39, 69, 82). As demonstrated by the Dynamical Model of Desire (31), wants that emerge into focal attention in working memory often instigate active pursuit of that desire. Weak,
transient desires, on the other hand, may go unnoticed, overshadowed by other desires, and may not result in any changes in behavior (45, 52). However, desires not in focal attention may still motivate behaviors with impelling force through an automatic route of influence. This may be the case for movement, the desire of which is often of a weaker nature, has a smaller demand for attention and exerts less influence on working memory than food or sleep. Nevertheless, it’s possible that desires for EE may play a key role in influencing movement behaviors and may help to explain compensatory responses to exercise (19).

### Conclusions

While models exist for cravings/desires for exercise, the systematic investigation of these constructs is still in its infancy, having been impeded by a lack of instrumentation. We developed a novel measurement tool to gauge the want / desire of movement and rest in 2 large groups of undergraduate students tested cross-sectionally, 2 groups tested multiple times per session and 1 group of community-dwelling adults assessed over a 2-year time period. Factor analyses determined that this instrument has good psychometric properties, distinguishing between desires for movement and rest. It is also sensitive to the state-like nature of the construct. Small changes were observed over a lecture period and large changes were observed with a bout of maximal exercise. Such a tool may be a valuable resource for researchers interested in psychological desires and how they relate to changes in physical activity and sedentary behaviors in the present moment. Future work should determine how these relate to facets of energy expenditure and whether satiating desires for movement and/or resisting desires for rest results in greater movement behavior.

### Acknowledgements

Marcus Kilpatrick, Ph.D. (University of South Florida) and Justin B. Moore, Ph.D. (Wake Forest School of Medicine) provided thoughtful comments on this project in its early stages. We would also like to acknowledge Samantha Brown (Icahn School of Medicine) for assistance with data management and graduate students from Teachers College, Columbia University, who provided many provoking insights.

### Funding

This work was supported in part by the National Institute of Diabetes and Digestive and Kidney Diseases/National Institutes of Health grant R01- DK099039 and the National Institutes of Health Roadmap for Medical Research Common Fund Grants UL1-DE019586, UL1-RR024139 (Yale Clinical and Translational Science Award), and the PL1-DA024859. GA is supported by a fellowship from the Office of Academic Affiliations at the United States Veterans Health Administration.
References

1. Anderson SE, Bandini LG, Dietz WH, Must A. Relationship between temperament, nonresting energy expenditure, body composition, and physical activity in girls. International Journal of Obesity. 2004;28(2):300-6.

2. Aristotle. De Anima iii. Raleigh, N.C.: Generic NL Freebook Publisher.

3. Bain A. The senses and the intellect. London: John W. Parker & Son; 1855.

4. Baldwin JM. Handbook of Psychology: Feeling and Will. New York: Henry Holt & Company; 1891.

5. Baldwin JM. Mental development in the child and the race: Methods and processes. New York: Macmillan; 1894.

6. Barke A, Baudewig J, Schmidt-Samoa C, Dechent P, Kröner-Herwig B. Neural correlates of fear of movement in high and low fear-avoidant chronic low back pain patients: an event-related fMRI study. Pain. 2012;153(3):540-52.

7. Bauman AE, Reis RS, Sallis JF, Wells JC, Loos RJF, Martin BW, et al. Correlates of physical activity: why are some people physically active and others not? Lancet. 2012;380(9838):258-71.

8. Beeler JA, Frazier CRM, Zhuang X. Putting desire on a budget: dopamine and energy expenditure, reconciling reward and resources. Frontiers in integrative neuroscience. 2012;6:49.

9. Beninger RJ. The role of dopamine in locomotor-activity and learning. Brain Research Reviews. 1983;6(2):173-96.

10. Berridge KC, Robinson TE. What is the role of dopamine in reward: hedonic impact, reward learning, or incentive salience? Brain Res Brain Res Rev. 1998;28(3):309-69.

11. Bohn MJ, Krahn DD, Staechner BA. Development and initial validation of a measure of drinking urges in abstinent alcoholics. Alcohol Clin Exp Res. 1995;19(3):600-6.

12. Brand R, Ekkekakis P. Affective–Reflective Theory of physical inactivity and exercise. German Journal of Exercise and Sport Research. 2018;48(1):48-58.

13. Buyukdura JS, McClintock SM, Croarkin PE. Psychomotor retardation in depression: Biological underpinnings, measurement, and treatment. Progress in Neuro-Psychopharmacology & Biological Psychiatry. 2011;35(2):395-409.

14. Chaplin WF, John OP, Goldberg LR. Conceptions of states and traits: dimensional attributes with ideals as prototypes. J Pers Soc Psychol. 1988;54(4):541-57.

15. Costello AB, Osborne JW. Best practices in exploratory factor analysis: Four recommendations for getting the most from your analysis. Practical Assessment, Research & Evaluation. 2005;10(7).

16. de Geus EJ, de Moor MH. Genes, exercise, and psychological factors. In: Bouchard C, Hoffman EP, editors. Genetic and molecular aspects of sports performance. Oxford: Blackwell Publishing; 2011. p. 294–305.

17. Ekkekakis P. Pleasure from the exercising body: Two centuries of changing outlooks in psychological thought. In: Ekkekakis P, editor. Routledge Handbook of Physical Activity and Mental Health. New York: Routledge; 2013. p. 35-56.

18. Ekkekakis P. Postscript. In: Ekkekakis P, editor. Routledge Handbook of Physical Activity and Mental Health. New York, NY: Routledge; 2013.

19. Ferreira A, Lamarque S, Boyer P, Perez-Diaz F, Jouvent R, Cohen-Salmon C. Spontaneous appetence for wheel-rolling: a model of dependency on physical activity in rat. European Psychiatry. 2006;21(8):580-8.

20. Garcia-Borreguero D, Stillman P, Benes H, Buschmann H, Chaudhuri KR, Rodriguez VMG, et al. Algorithms for the diagnosis and treatment of restless legs syndrome in primary care. Bmc Neurology. 2011;11:12.

21. Garland T, Schutz H, Chappell MA, Keeney BK, Meek TH, Copes LE, et al. The biological control of voluntary exercise, spontaneous physical activity and daily energy expenditure in relation to obesity: human and rodent perspectives. Journal of Experimental Biology. 2011;214(2):206-29.

22. Good DJ, Coyle CA, Fox DL. Nhlh2: A basic helix-loop-helix transcription factor controlling physical activity. Exercise and Sport Sciences Reviews. 2008;36(4):187-92.
23. Haber SN, Calzavara R. The cortico-basal ganglia integrative network: the role of the thalamus. Brain Res Bull. 2009;78(2-3):69-74.

24. Hausenblas HA, Downs DS. Exercise dependence: a systematic review. Psychology of Sport and Exercise. 2002;3(2):89-123.

25. Hay JA. Adequacy in and predilection for physical activity in children. Clinical Journal of Sport Medicine. 1992;2(3):192-201.

26. Heishman SJ, Evans RJ, Singleton EG, Levin KH, Copersino ML, Gorelick DA. Reliability and validity of a short form of the Marijuana Craving Questionnaire. Drug and Alcohol Dependence. 2009;102(1-3):35-40.

27. Herring MP, O'Connor PJ. The effect of acute resistance exercise on feelings of energy and fatigue. Journal of Sports Sciences. 2009;27(7):701-9.

28. Hoffman GJ, Lee J, Mendez-Luck CA. Health Behaviors Among Baby Boomer Informal Caregivers. Gerontologist. 2012;52(2):219-30.

29. Hoffman MD, Hoffman DR. Exercisers achieve greater acute exercise-induced mood enhancement than nonexercisers. Archives of Physical Medicine and Rehabilitation. 2008;89(2):358-63.

30. Hofmann W, Baumeister RF, Forster G, Vohs KD. Everyday Temptations: An Experience Sampling Study of Desire, Conflict, and Self-Control. Journal of Personality and Social Psychology. 2012;102(6):1318-35.

31. Hofmann W, Van Dillen L. Desire: The new hot spot in self-control research. Current Directions in Psychological Science. 2012;21(5):317-22.

32. Hofmann W, Vohs KD, Baumeister RF. What People Desire, Feel Conflicted About, and Try to Resist in Everyday Life. Psychological Science. 2012;23(6):582-8.

33. Hu LT, Bentler PM. Cutoff Criteria for Fit Indexes in Covariance Structure Analysis: Conventional Criteria Versus New Alternatives. Structural Equation Modeling-a Multidisciplinary Journal. 1999;6(1):1-55.

34. Hutchinson JC, Sherman T, Davis L, Cawthon D, Reeder NB, Tenenbaum G. The influence of asynchronous motivational music on a supramaximal exercise bout. International Journal of Sport Psychology. 2011;42(2):135-48.

35. Iqbal N, Lambert T, Masand P. Akathisia: Problem of history or concern of today. Cns Spectrums. 2007;12(9):1-4.

36. Jastreboff AM, Sinha R, Lacadie C, Small DM, Sherwin RS, Potenza MN. Neural Correlates of Stress- and Food Cue-Induced Food Craving in Obesity Association with insulin levels. Diabetes Care. 2013;36(2):394-402.

37. Jung Y, Hassan A, St Louis EK, Robertson CE. Restless mouth syndrome. Neurol Clin Pract. 2017;7(3):e29-e30.

38. Katula JA, Sipe M, Rejeski WJ, Focht BC. Strength training in older adults: an empowering intervention. Med Sci Sports Exerc. 2006;38(1):106-11.

39. Kemps E, Tiggemann M. Competing Visual and Olfactory Imagery Tasks Suppress Craving for Coffee. Experimental and Clinical Psychopharmacology. 2009;17(1):43-50.

40. Kessler RC, Andrews G, Colpe LJ, Hiripi E, Mroczek DK, Normand SL, et al. Short screening scales to monitor population prevalences and trends in non-specific psychological distress. Psychol Med. 2002;32(6):959-76.

41. Kline RB. Principles and practice of structural equation modeling. 3rd ed. New York: Guilford Press; 2010.

42. Levine JA, Lanningham-Foster LM, McCrady SK, Krizan AC, Olson LR, Kane PH, et al. Interindividual variation in posture allocation: Possible rote in human obesity. Science. 2005;307(5709):584-6.

43. Levitin DJ, Grahn JA, London J. The Psychology of Music: Rhythm and Movement. Annu Rev Psychol. 2018;69:51-75.

44. Lewin K. Field theory in social science. 1951.

45. Loewenstein G. Out of control: Visceral influences on behavior. Organizational Behavior and Human Decision Processes. 1996;65(3):272-92.
46. Marcus BH, Rakowski W, Rossi JS. Assessing motivational readiness and decision-making for exercise. Health Psychology. 1992;11(4):257-61.

47. Matthews TE, Witek MAG, Heggli OA, Penhune VB, Vuust P. The sensation of groove is affected by the interaction of rhythmic and harmonic complexity. PLoS One. 2019;14(1):e0204539-e.

48. Mogenson GJ, Jones DL, Yim CY. From motivation to action- Functional interface between the limbic system and the motor system. Progress in Neurobiology. 1980;14(2-3):69-97.

49. Nascimento DS. Desire and cognition in Aristotle’s theory of the voluntary movements of animal locomotion. Filosofia Unisinos. 2017;18:70-8.

50. O'Connor PJ. Evaluation of four highly cited energy and fatigue mood measures. Journal of Psychosomatic Research. 2004;57(5):435-41.

51. Owen N, Healy GN, Matthews CE, Dunstan DW. Too Much Sitting: The Population Health Science of Sedentary Behavior. Exercise and Sport Sciences Reviews. 2010;38(3):105-13.

52. Papiès EK, Barsalou LW. Grounding desire and motivated behavior: A theoretical framework and review of empirical evidence. In: Hofmann W, Nordgren LF, editors. The Psychology of Desire. New York: Guilford Press; 2015.

53. Pettee Gabriel KK, Morrow JR, Jr., Woolsey A-LT. Framework for physical activity as a complex and multidimensional behavior. Journal of physical activity & health. 2012;9 Suppl 1:S11-8.

54. Piercy KL, Troiano RP, Ballard RM, Carlson SA, Fulton JE, Galuska DA, et al. The Physical Activity Guidelines for Americans. JAMA. 2018;320(19):2020-8.

55. Rauch HGL, Schönbaechler G, Noakes TD. Neural correlates of motor vigour and motor urgency during exercise. Sports Medicine. 2013;43(4):227-41.

56. Recordati G. A thermodynamic model of the sympathetic and parasympathetic nervous systems. Autonomic Neuroscience-Basic & Clinical. 2003;103(1-2):1-12.

57. Redden JP. Desire over time: The multifaceted nature of satiation. The psychology of desire. New York, NY, US: The Guilford Press; 2015. p. 82-103.

58. Reiss S. Multifaceted nature of intrinsic motivation: The theory of 16 basic desires. Review of General Psychology. 2004;8(3):179-93.

59. Robbins TW, Everitt BJ. A role for mesencephalic dopamine in activation: commentary on Berridge (2006). Psychopharmacology (Berl). 2007;191(3):433-7.

60. Roberts MD, Gilpin L, Parker KE, Childs TE, Will MJ, Booth FW. Dopamine D1 receptor modulation in nucleus accumbens lowers voluntary wheel running in rats bred to run high distances. Physiology & Behavior. 2012;105(3):661-8.

61. Robinson TE, Berridge KC. The neural basis of drug craving: An incentive-sensitization theory of addiction. Brain Research Reviews. 1993;18(3):247-91.

62. Rowland TW. The biological basis of physical activity. Medicine and Science in Sports and Exercise. 1998;30(3):392-9.

63. Ruppert E. Restless arms syndrome: prevalence, impact, and management strategies. Neuropsychiatr Dis Treat. 2019;15:1737-50.

64. Russell DW. In search of underlying dimensions: The use (and abuse) of factor analysis in Personality and Social Psychology Bulletin. Personality and Social Psychology Bulletin. 2002;28(12):1629-46.

65. Salamone JD. Complex motor and sensorimotor functions of striatal and accumbens dopamine-involvement in instrumental behavior processes. Psychopharmacology. 1992;107(2-3):160-74.

66. Sayette MA, Wilson SJ. The measurement of desires and craving. In: Hofmann W, Nordgren L, editors. The Psychology of Desire. New York; Guilford Press; 2015.

67. Shields C. Aristotle’s De Anima, tranlsated with commentary. Oxford2016.

68. Singleton EG, Tiffany ST, Henningfield JE. Alcohol Craving Questionnaire (ACQ-NOW): Background, Scoring, and Administration (Manual). Baltimore, MD: Intramural Research Program, National Institute on Drug Abuse; 2000.
WANTS / DESIRES FOR PHYSICAL ACTIVITY

69. Sinha R. How does stress increase risk of drug abuse and relapse? Psychopharmacology. 2001;158(4):343-59.
70. Sinha R. The clinical neurobiology of drug craving. Current Opinion in Neurobiology. 2013;23(4):649-54.
71. Sinha R, Gu P, Hart R, Guarnaccia JB. Food craving, cortisol and ghrelin responses in modeling highly palatable snack intake in the laboratory. Physiol Behav. 2019;208:112563.
72. Skinner GW, Mitchell D, Harden LM. Avoidance of physical activity is a sensitive indicator of illness. Physiol Behav. 2009;96(3):421-7.
73. Stedman HR. Rest and exercise in the treatment of nervous and mental disease. Boston Medical and Surgical Journal. 1896;CXXXIV:645-6.
74. Stults-Kolehmainen MA, Ciccolo JT, Bartholomew JB, Seifert J, Portman RS. Age and Gender-related Changes in Exercise Motivation among Highly Active Individuals. Athletic Insight. 2013;5(1):45-63.
75. Stults-Kolehmainen MA, Gilson TA, Abolt CJ. Feelings of acceptance and intimacy among teammates predict motivation in intercollegiate sport. Journal of Sport Behavior. 2013;36(3).
76. Stults-Kolehmainen MA, Sinha R. The effects of stress on physical activity and exercise: A systematic review. Sports Medicine. 2014;44(1):81-121.
77. Terry PC, Stevens MJ, Lane AM. Influence of response time frame on mood assessment. Anxiety Stress and Coping. 2005;18(3):279-85.
78. Thayer RE. Activation-Deactivation Adjective Check List: Current Overview and Structural Analysis. Psychological Reports. 1986;58(2):607-14.
79. Thayer RE. Problem perception, optimism, and related states as a function of time of day (diurnal rhythm) and moderate exercise: 2 arousal systems in interaction. Motivation and Emotion. 1987;11(1):19-36.
80. Thompson D, Batterham AM. Towards Integrated Physical Activity Profiling. PLoS One. 2013;8(2):9.
81. Tiffany ST. A critique of contemporary urge and craving research: Methodological, psychometric and theoretical issues. Advances in Behaviour Research and Therapy. 1992;14(3):123-39.
82. Tiggemann M, Kemps E. The phenomenology of food cravings: The role of mental imagery. Appetite. 2005;45(3):305-13.
83. Vago DR, Zeidan F. The brain on silent: mind wandering, mindful awareness, and states of mental tranquility. Ann N Y Acad Sci. 2016;1373(1):96-113.
84. Van der Elst W, Molenberghs G, Hilgers D, Heussen N. CorrMixed: Estimate Correlations Between Repeatedly Measured Endpoints (E.g., Reliability) Based on Linear Mixed-Effects Models. R Package Version 1.0 2018 [Available from: https://CRAN.R-project.org/package=CorrMixed.
85. Watson D. Intraindividual and Interindividual Analyses of Positive and Negative Affect: Their Relation to Health Complaints, Perceived Stress, and Daily Activities Journal of Personality and Social Psychology. 1988;54(6):1020-30.
86. Williams DM, Dunsiger S, Ciccolo JT, Lewis BA, Albrecht AE, Marcus BH. Acute affective response to a moderate-intensity exercise stimulus predicts physical activity participation 6 and 12 months later. Psychology of Sport and Exercise. 2008;9(3):231-45.
87. Williams DM, Evans DR. Current Emotion Research in Health Behavior Science. Emotion Review. 2014;6(3):277-87.
88. Windle M, Lerner RM. Reassessing the Dimensions of Temperamental Individuality Across the Life Span: The Revised Dimensions of Temperament Survey (DOTS-R). Journal of Adolescent Research. 1986;1(2):213-30.