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Abstract

Self-control is reflected by increased heart rate variability (HRV) (Segerstrom & Solberg Nes 2007). Since HRV can be modulated by respiratory rate (Song & Lehrer 2003), it may be hypothesized that breathing affects self-control. This relationship has not yet been directly investigated. The present study experimentally tested the hypothesis that paced respiratory patterns have immediate short-term effects on people's capability to resist distraction through attentional impulse control. The experiment had 50 participants perform a brief breathing exercise, either slow- or fast-paced. This was followed by the instruction to focus their attention on a video screen in front of them, on which boring footage was displayed. Another screen positioned to the right simultaneously showed exciting, attention-grabbing video clips with audio. Self-control was measured by the amount and duration of subjects' gazes toward the distractor screen. The results showed that subjects in the fast breathing group gazed more often and longer at the distractor screen than subjects in the slow breathing group—thus supporting the hypothesis. Additional measurements of time interval since the last meal consumed as well as neuroticism score could each partially predict self-control performance, whilst psychostimulant intake, leisure-time physical activity score, and participants' beliefs about willpower could not. Some heart rate variability measures reflected self-regulatory strength but did not differ between groups during self-regulatory effort. After discussing these results, limitations of the study, and its relevance for cognitive science, the thesis ends with proposals for future research and a conclusion.

Keywords: attentional impulse control, self-control, self-regulation, willpower, cognitive performance, respiration, breathing exercise, heart rate variability, executive function task, distracting video clips, auditory stimuli, Big Five personality traits, neuroticism.

Introduction

Self-control matters. In psychological studies, high scores on self-control tests correlated with greater academic success (Duckworth & Seligman 2005), fewer reports of psychopathology (Tangney et al. 2004), and better psychological adjustment and interpersonal skills (ibid.) as well as longevity (Kern & Friedman 2008), health (Moffitt et al. 2011), and wealth (ibid.). Although an individual's self-control is partly determined by personality factors, especially conscientiousness and emotional stability (Tangney et al. 2004), willpower follows a similar dynamic as skeletal muscles and thus is trainable through exercise (McGonigal 2013). According to the strength model of self-control (Hagger et al. 2010), willpower is a limited mental resource that can be exhausted by exerting self-regulatory strength (Baumeister et al. 1998) or making choices (Vohs et al. 2008), temporarily leading to impaired self-control task performance. The corresponding concept of ego depletion, which suggests a limited pool of willpower, can be reframed in terms of the muscle metaphor as self-regulatory fatigue to reflect the fact that external motivation can override this effect, which is, as Segerstrom and colleagues (2012) claim, possible with fatigue but not depletion. When a skeletal muscle is fatigued, parasympathetic nervous system activity allows the muscle to recover (Chen et al. 2011). Slow, deep breathing has been shown to foster this process (Jerath et al. 2006). If the muscle model of self-control holds true, relaxing breathing patterns could similarly be expected to promote recovery after self-regulatory fatigue and thus to improve willpower.

In the Far East, students of traditions like Yoga, Zen, or Martial Arts have been practicing breathing techniques to exercise affective self-mastery for decades. In Traditional Chinese Medicine, breathing is said to impact willpower (zhi) by modulating Jing and thus the

Qi in our kidneys (Batliner 2004). More recently, a plethora of scientific studies have repeatedly found self-regulation of respiration to effectively help deal with negative affective states including stress, anxiety, and depression (Jerath et al. 2015). Even the sympathetic nervous system and the immune system can be voluntarily influenced via certain breathing techniques (e.g., Kox et al. 2014). This motivates the present study's guiding question: can voluntary breathing, in addition to regulating some affective and autonomous processes, also affect self-regulation on the more abstract level of conscious goals?

Willpower is the self-regulatory strength required for all acts of self-control through which an individual can either initiate and adhere to novel, boring, difficult, exhausting, or stressful tasks or refrain from surrendering to unwanted impulses or cravings. In this study, willpower or self-control is defined as the ability to consciously control one's behavior in alignment with one's longer-term goals in the face of conflicting thoughts, emotions, and desires driving impulsive behaviors toward opposing shorter-term goals. Furthermore, I regard willpower as the "fuel" for executive functions, which are cognitive control processes "essential for achieving a particular goal in a flexible and appropriate manner" (Funahashi & Andreau 2013, p. 471). Examples include attentional control and behavioral response inhibition (e.g., Funahashi 2001).

From an evolutionary perspective, primates' executive functions with self-regulatory capacity might have been selected for as an adaptation to the demands of increasing social complexity on cognition (Dunbar 2003). Fitting in, cooperating, and maintaining long-term relationships were needs that put evolutionary pressure on our early human brains to develop strategies for self-regulation (McGonigal 2013). Neurophysiologically, willpower is based on the parasympathetic pause-and-plan response of the nervous system (Segerstrom et al. 2012), and its exertion in the form of volitional impulse control or response inhibition is

associated with activity in the prefrontal cortex (Suchy 2009, Sapolsky 2004, Picton et al. 2007) and the anterior cingulate cortex (ACC) (Inzlicht & Gutsell 2007).

A physiological phenomenon called heart rate variability (HRV) is also connected to both prefrontal and ACC activity (Lane et al. 2009, Thayer et al. 2009, Vanneste & De Ridder 2013, Matthews et al. 2004). HRV is the variation in the time interval between consecutive heartbeats (Acharya 2006), typically R-spikes in consecutive QRS complexes. As a measure of autonomic balance, HRV is being widely recognized as a crucial biomarker for healthy heart function, risk of all-cause mortality, psychopathology (Thayer et al. 2009), and various health conditions (McCraty & Shaffer 2015, Thayer & Lane 2007), especially cardiovascular disease (Thayer et al. 2010) and posttraumatic stress disorder (Zucker et al. 2009). Higher HRV in particular has been consistently associated with healthier human organisms. In addition, psychophysiological studies investigating cognitive performance have repeatedly found higher HRV to be a reliable predictor of increased speed and accuracy on tasks that tax executive functions (Thayer et al. 2009, Hansen et al. 2004, Hansen et al. 2003). In their study based on questionnaire data, Fabes and Eisenberg (1997) found higher vagal tone to be correlated with better stress coping capabilities as well as with greater regulatory control. Geisler and Kubiak (2009) assessed inhibitory capacity subsequent to a failure experience in terms of self-confidence before an action as well as rumination after an action. As both of these indices of self-regulatory strength were correlated with HRV, their results demonstrated that inhibitory self-control can be measured by HRV (Geisler & Kubiak 2009).

Rather than relying on self-report data, Segerstrom and Solberg Nes (2007) had 168 subjects either resist or indulge in chocolate cookies and then persist at a difficult anagram

task. In accordance with the theory of ego depletion (Baumeister et al. 1994) or self-regulatory fatigue (Muraven & Baumeister 2000), subjects who could indulge in cookies, thus exerting less willpower, subsequently persisted significantly longer at the anagram task as compared to those who had to fatigue their self-control muscle by resisting the temptation (Segerstrom & Solberg Nes 2007). Furthermore, higher self-regulatory efforts elevated HRV, and higher baseline HRV predicted longer persistence at the anagram task. Since the self-control conditions had distinctly different effects on behavioral and physiological variables than a simple stress condition (which lowered HRV), the authors concluded that HRV provides an index of self-regulatory strength and effort.

Reynard and colleagues (2011) attempted to replicate these results while also accounting for physical activity scores. With the claim that consumption of chocolate cookies might have increased self-regulatory strength through elevated brain glucose levels (cf. Gailliot et al. 2007), they replaced the food condition by the instruction to think of a white bear (low self-regulation condition) or to not think about a white bear (high self-regulation condition). While baseline HRV was found to be positively correlated with longer subsequent persistence on an unsolvable anagram, condition-dependent HRV relative to the baseline underwent a decrease in both groups. This is inconsistent with the results of the study by Segerstrom and Solberg Nes (2007), yet consistent with the finding by Wood et al. (2002) that a cognitive effort reduced short-term HRV. Moreover, higher leisure-time exercise scores were associated with less difference between the effects of the two self-regulation conditions on self-control fatigue, suggesting that physical exercise may delay self-regulatory failure (Reynard et al. 2011).

HRV crucially depends on the organism's given situational context, particularly on the stressors the organism is exposed to. Resting or baseline HRV—and thus potentially basal

self-regulatory strength—can be influenced by a myriad of different factors including general physical activity and exercise (Sandercock et al. 2005, Hansen et al. 2004), habits such as meditation or mindfulness practice (Peressutti et al. 2010, Tang et al. 2009), regular heart coherence training (McCraty & Shaffer 2015), sleep and recovery (Nam et al. 2011), nutrition (Christensen 2003), environmental air quality (Park et al. 2008), social environment (Grippio et al. 2011), chronic pain and illness (Solberg Nes et al. 2010), substance abuse (Ingjaldsson et al. 2003), and affective states and disorders (McCraty et al. 2009, Taylor 2010). However, the most direct influencing factor on HRV, besides posture (Nam et al. 2011), is respiration.

Respiratory Sinus Arrhythmia (RSA), a measure of parasympathetic nervous system activity, describes the naturally occurring variation in heart frequency in synchronicity with breathing: a resting person's heart rate increases during inspiration and decreases during expiration (Hirsch and Bishop 1981). This respiration-related modulation of the heart rhythm is usually (at normal respiratory cycles) vagally mediated (Grossman & Taylor 2007) and reflected in heart rate oscillations in the high-frequency band (0.15-0.4 Hz) (Song & Lehrer 2003). However, during periods of slow respiration frequencies, i.e., below 8.5 breaths per minute, or when an individual sighs or takes a deep breath, vagal activity can generate heart rhythm oscillations that cross over into the low-frequency band (0.04-0.15 Hz) (McCraty & Shaffer 2015). Practitioners in the rapidly flourishing field of heart coherence and HRV biofeedback training are abundantly aware of and seem to have extensive clinical knowledge about the dynamics between breathing and HRV. A scientific study on yoga practitioners found that some techniques that prolong the respiratory cycle, especially

Ujjayi¹ breathing, elevated HRV (Kovacs 2012). Another study suggested that a daily deep, slow breathing exercise for one month increased HRV in healthy subjects (Tharion et al. 2012). Song and Lehrer (2003) systematically looked at specific respiratory strategies, namely five female subjects breathing at rates of 3, 4, 6, 8, 10, 12, and 14 cycles per minute. Their results suggested an inverse relationship between HRV and respiratory rate, with the exception that HRV amplitude peaks at four breaths per minute but declines as the frequency drops below that.

Despite the extensive research on how breathing influences HRV and some studies on how HRV reflects self-regulatory strength, experimental data on a direct link between breathing and self-regulation is sparse to non-existent. In her book *The Willpower Instinct*, Kelly McGonigal (2013) suggests that self-regulatory strength can be immediately amplified by slowing down one's breathing. Her rationale is that lowering respiratory frequency activates the prefrontal cortex and increases heart rate variability, which helps deal with the autonomic stress response by shifting the nervous system to pause-and-plan, self-control mode. As has been shown above, this reasoning is well-founded in empirical studies. In addition, longitudinal studies have applied programs consisting of repeated extensive (20- to 60-minute) training sessions including Yoga, breathing, and meditation exercises. Their results have found positive effects on stress resilience and self-control (Ramadoss & Bose 2010, Tang et al. 2007). However, no studies have yet investigated the immediate effects of breathing on willpower, let alone self-regulatory efforts evaluated by actual behavior rather than mere questionnaire data.

¹ Ujjayi Pranayama is a diaphragmatic breath technique, which successively fills the lower belly, the lower rib cage, and eventually the upper chest and throat with air whilst decelerating airflow in the pharynx.

To fill this gap of knowledge and to empirically substantiate Kelly McGonigal's breath technique proposal for quickly boosting willpower is the objective of the present study. Inhibitory capacity, a key feature of self-regulatory strength or willpower (Muraven & Baumeister 2000), will be evaluated in terms of people's capability of resisting distraction through selective visual attention. Like other cognitive functions, attentional control depends upon working memory (Thayer et al. 2009). In order to pursue the question of whether it may additionally depend on some kind of physiological working memory, it is hypothesized that brief, paced respiratory patterns have immediate short-term effects on people's capability to resist distraction through attentional impulse control. This hypothesis predicts that, on average, subjects in a slow breathing group (3.75 breaths per minute) gaze significantly less, in both amount and duration, at a prohibited distractor screen, in comparison to subjects in a fast breathing group (15 breaths per minute). Furthermore, I expect willpower performance to be correlated with HRV, Big Five personality traits, and physical activity score.

Methods

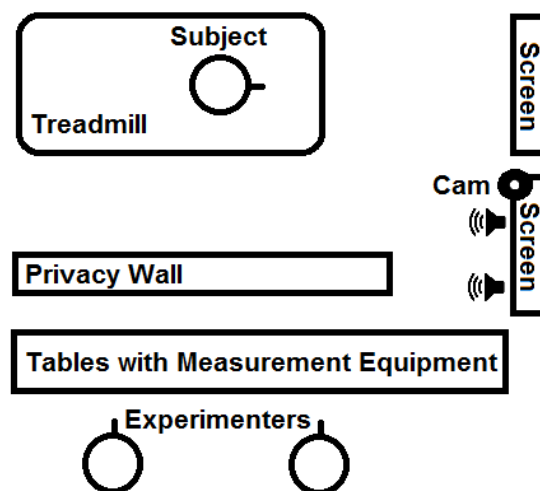
Participants. 50 German speaking, mostly heterosexual (two bisexual, no homosexual) individuals, mostly college students (93.9%) of European descent (87.2%), participated in the experiment. Three subjects were excluded from further analysis: two because they belonged to a control group that was later abandoned due to sample size limitations, and one because her eye movements were not distinctively discernible for video coding. The remaining sample was composed of 27 females and 20 males of the age of 18-35 (females: $M = 24.46$ yrs., $SD = 3.46$ yrs.; males: $M = 25.81$ yrs., $SD = 3.64$ yrs.). Twelve subjects had consumed caffeine within five hours before the experiment, five more subjects had also consumed nicotine. Other psychoactive substances had not been consumed by any subjects, nor any medication indicating cardio-respiratory illnesses, executive dysfunctions, or affective disorders. According to self-reports, the majority of participants felt fairly to very fit (84.2%), had slept at least seven hours during the previous night (84.2%), and maintained a general intention to eat healthily (86.8%). Only six subjects practiced meditation², Yoga, or breathing exercises on a daily basis. In terms of education, 42.6% of participants had some university experience, 25.5% had completed a bachelor's degree, 17.4% had completed a master's degree, and 6.4% held a PhD.

Materials. Motion tracking via 18 inertial motion sensors and movement on a treadmill was inherited from a prior experiment and lacked particular relevance to the present study. Two sensor belts, Polar Transmitter SP0180 and Respiratory Belt Transducer MLT1132, were connected to PowerLab and then to a Mac computer running *LabChart*. The setup of the laboratory is schematically depicted in Fig. 1. The two HD video screens by Dell—one

² The habit of meditation was inquired because of its impact on attentional control (cf. Malinowski 2013).

the attentional target, the other the distractor screen—were 28 inches in diagonal size, and the webcam, Logitech QuickCam Pro 9000, was placed on top of the right screen. The video input provided by two Mac computers (one for each screen) was automatized for synchronization by a presentation software written by Prof. Karl Grammer and adapted by Anna Schaman, MSc.

FIGURE 1
SKETCH OF LABORATORY FACILITIES



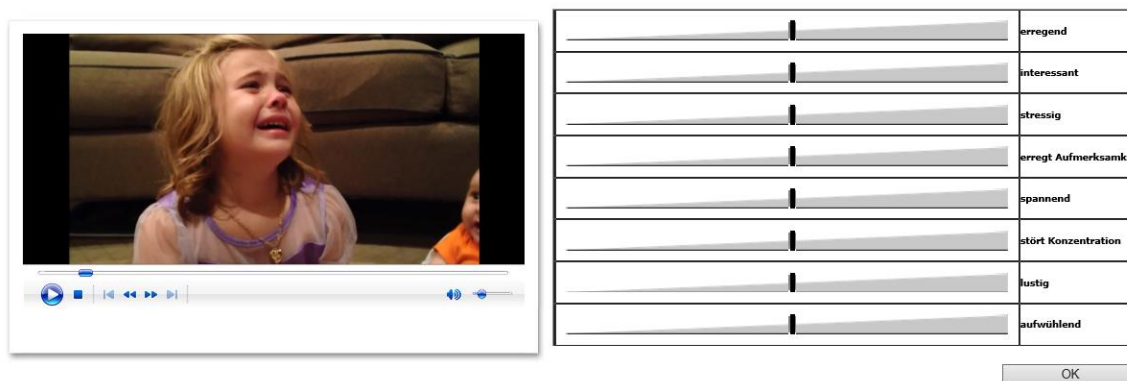
The post-task questionnaires were a German version of the 25-item Big Five Inventory by John et al. (1991) (see Appendix A) as well as a custom questionnaire (see Appendix B) inquiring over demographic data, self-perceived performance, and other information including leisure-time physical activity (based on Godin & Shephard 1997). The post-task snacks offered during the questionnaire phase were one energy drink (125 kcal), one sugar-free energy drink (8 kcal), four fruit bars (98 kcal each), four different chocolate bars (106 kcal each on average), two rice cakes (27 kcal each), two chocolate rice cakes (83 kcal each), and a glass of fresh water.

Stimuli. The instructions for the breathing exercise displayed on the attentional target screen started with “Atemübung. Bitte folgen Sie den Anweisungen” (“Breathing Exercise.

Please follow the instructions”), followed by the commands “Einatmen” for breathing in, “Ausatmen” for breathing out, and, additionally for the slow breathing group, “Luft anhalten” for holding breath—all with a countdown number indicating the remaining seconds for each phase. All typefaces were in plain black written on a white background. During the instructed breathing phase, the distractor screen was turned off. It turned on during the executive-function task showing a set of five video clips (total length: 193 seconds in the first round, 228 seconds in the second), while a screensaver with slowly changing colors was being displayed on the attentional target screen.

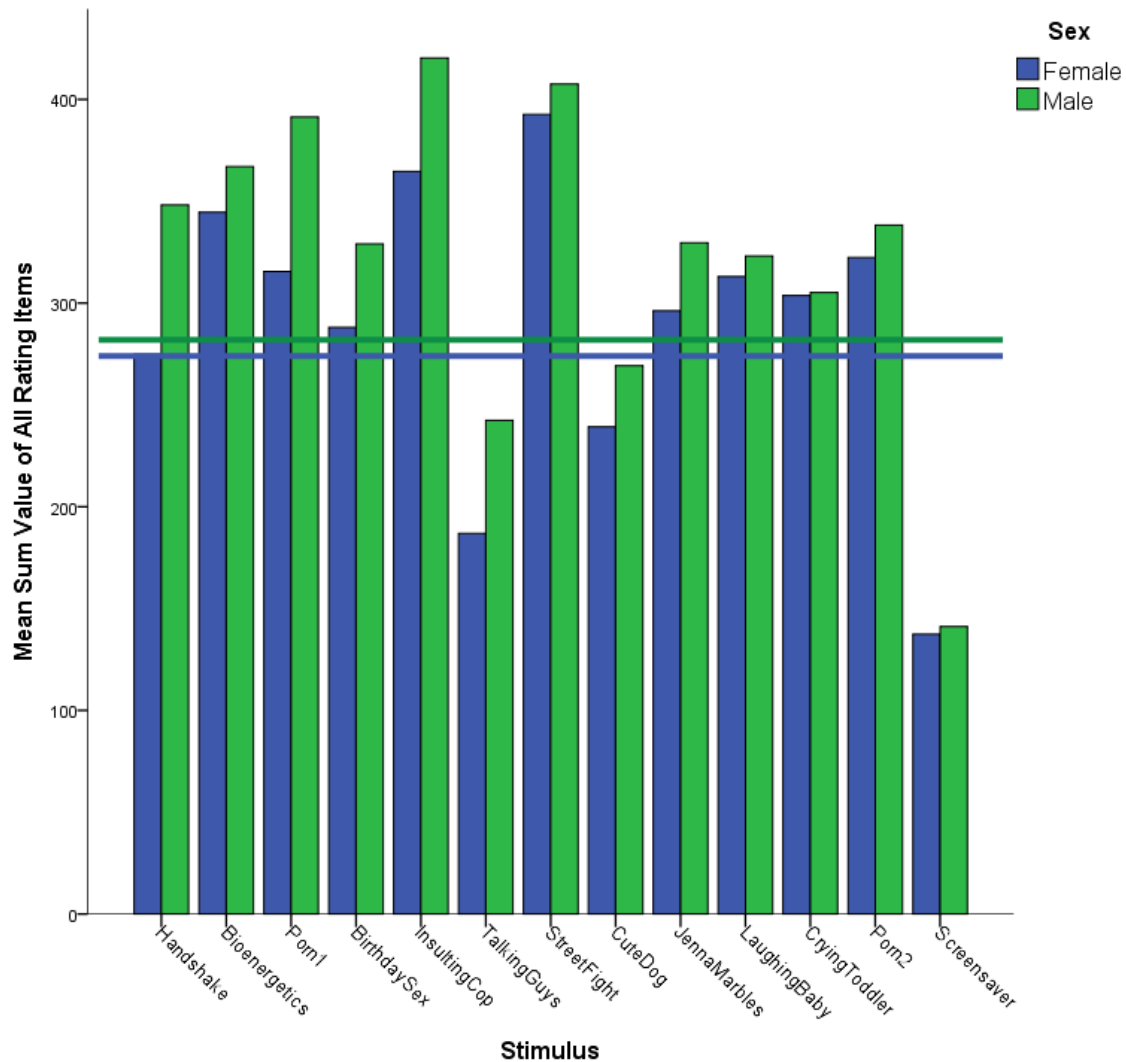
Pre-Study. To evaluate the attention-grabbing potential of these clips and thus their appropriateness for an executive-function task, a pre-study was conducted in March 2015. A total of 39 German-speaking subjects (18 male, 21 female) of the age of 18-33 (females: $M = 23.57$ yrs., $SD = 3.78$ yrs.; males: $M = 24.33$ yrs., $SD = 3.77$ yrs.), who were informed that they were about to see potentially unsettling video footage containing violent and pornographic content, rated a collection of 13 short video clips (ranging from 14 to 76 seconds in length, 510 seconds in total) presented in random order by means of the open-source rating program *Emotional Systems* (see Fig. 2, Grammer et al. 2013) on a laptop equipped with headphones.

FIGURE 2
USER INTERFACE OF OPEN-SOURCE RATING SOFTWARE *EMOTIONAL SYSTEMS*



Eight items—“erregend” (exciting), “interessant” (interesting), “stressig” (stressful), “erregt Aufmerksamkeit” (attracts attention), “spannend” (thrilling), “stört Konzentration” (disturbs concentration), “lustig” (funny), and “aufwühlend” (disturbing)—were each rated on a scale from 0 to 100 for every stimulus by moving a slider using a touchpad. Fig. 3 depicts the mean sum values of all rating items for each stimulus. The two horizontal lines mark, separately for each sex, the mean sum value that is twice as much as the one for the baseline stimulus (Screensaver) that was intended to be perceived as faintly attention-grabbing.

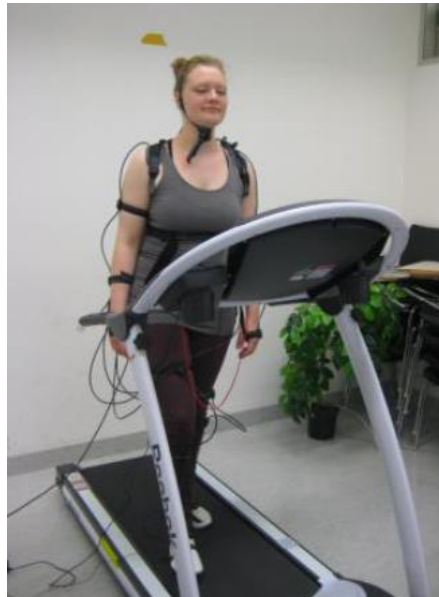
FIGURE 3
RESULTS OF PRE-STUDY FOR EVALUATION OF VIDEO STIMULI



Based on the observed distribution, a gender-segregated double-value criterion was applied to the rating results, which was met by ten video clips. These were then grouped into two sets of five clips each as distracting stimuli for the behavioral experiment. When initially retrieving the individual clips from <http://youtube.com> and <http://youporn.com>, the main search and selection criterion was to find footage of non- or minimally-staged human activities and social interactions that humans are evolutionarily bound to be affected by on a visceral level; for instance, reproduction (sex and infants) and social group dynamics (violence and aggression). The clips were cut using *Windows Movie Maker 2012*.

Procedure. Data were collected over five weeks in May and June 2015 between 9 am and 9 pm, with each session lasting for an average of 92 minutes ($SD = 17$ min.). Upon arrival in the laboratory, two experimenters welcomed the subject and took initial measurements (body height, body weight, and finger scans). The subject was then equipped with three sensor devices: a heart frequency belt around the lower thorax, a piezoelectric breathing belt around the mid-torso, and a cable structure interspersed with 18 sensors over the entire body (see Fig. 4).

FIGURE 4
SUBJECT EQUIPPED WITH MEASUREMENT DEVICES ON TREADMILL



As soon as signal quality was ascertained, the subject stepped on a treadmill and chose her preferred walking speed under the restriction that it must remain unaltered throughout the experiment: chosen treadmill velocity ranged from 0.6 km/h (the lower technical limit) to 2.5 km/h ($M = 1.16$ km/h, $SD = .47$ km/h). During an approximate total of 60 minutes of alternating standing and walking on the treadmill, the subjects, who were offered a glass of water to drink when standing, underwent two subsequent experimental procedures (see Appendix D for the detailed laboratory procedure). The first was a thematically unrelated experiment consisting of seven rounds of different emotion-eliciting video stimuli followed by an emotional state questionnaire and a Stroop test to investigate the relationship between motion and emotion. After which came the present study's experiment consisting of two rounds of a breathing exercise each followed by an executive-function task. The breathing exercise divided all 47 subjects randomly into two different groups: a slow breathing group (12 females, 11 males) and a fast breathing group (14 females, 10 males). The breathing instructions were displayed on a screen in front of the treadmill—six sixteen-second breathing cycles (4 seconds inspiration, 4 seconds pause, 8 seconds expiration³) for the slow breathing group and twenty-four four-second breathing cycles (2 seconds inspiration, 2 seconds expiration) for the fast breathing group. After the breathing exercise, subjects were instructed to keep their attention focused on the left-hand screen (the screen in front of them) for the rest of the experiment. Subsequently, a screensaver (monotonous stimulus) was displayed on that screen, while a set of video clips (attention-grabbing stimulus) was displayed

³ Subjects in the slow breathing group were not explicitly instructed to breathe deeply. Rather, the long expiration period of eight seconds was chosen deliberately to automatically induce deeper breathing.

on another screen placed 50 cm to the right of the first one (see Fig. 5). This distractor screen also emitted audio output.

FIGURE 5
EXPERIMENT FROM THE SUBJECT'S PERSPECTIVE

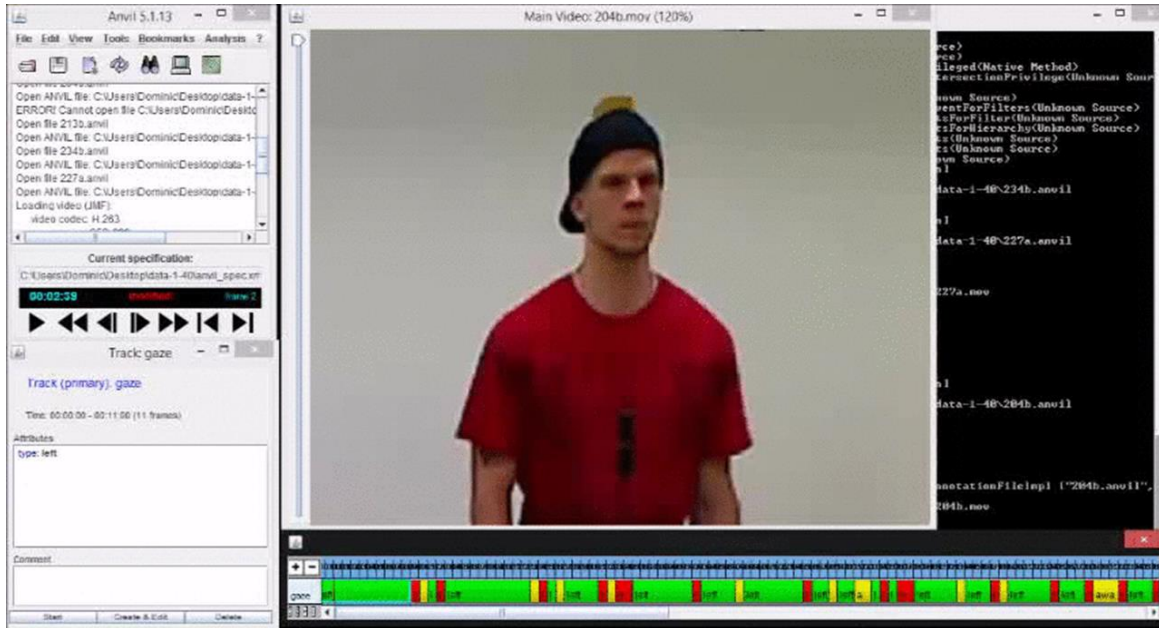


The two experimental rounds lasted for twelve minutes including a one-minute break for resetting the software in between. Thereafter, subjects stepped off the treadmill, were disconnected from all measurement devices, and led to another room where they would, in privacy, fill in two questionnaires while optionally consuming a variety of snacks provided to them. Upon completion, they were informed about the nature, hypotheses, and implications of the study as well as about the presence of a video camera that recorded them throughout the experimental process. Subjects were asked to fill in a form (see Appendix C) to give their consent that they participated voluntarily, had been informed about the meaning and purpose of the study, and that the data recorded during the experiment may be

used by the University of Vienna for scientific purposes. Eventually, each participant received five euros as compensation for their time.

Behavior Analysis. The video material of the subjects' behavior produced during the experiment was first sampled down to 1 fps and cropped to capture solely subjects' upper bodies using *AviDemux* 2.6.9. The reason for downsampling was to reduce, during later frame-by-frame coding, the chance of registering microsaccades, which are, though modulated by visual attention (Engbert & Kliegl 2003), by definition involuntary eye movements (Ciuffreda & Tannen 1995) and thus no indices of attentional self-control. *XMedia Recode* 3.2.3.0 was used to convert the processed clips to QuickTime format (MOV with H.263 codec). Behavioral gaze analysis of the resulting files was done by observation-based frame-by-frame coding using the video annotation research tool *Anvil* 5.1.13 (Kipp 2001, see Fig. 6). The Anvil specification file consisted of one single track "gaze" with three different attributes: "left" (green), "right" (red), and "away" (yellow) to account for the entire spectrum of relevant gaze behaviors, namely, looking at the target screen on the left, gazing at the distractor screen on the right, and looking away or having eyes closed.

FIGURE 6
SCREENSHOT OF ANVIL USER INTERFACE AND CUSTOM CODING SPECIFICATION



One researcher manually coded all 2x47 video clips (two experimental rounds for each subject) without respect to the subjects' group affiliations. Neither the "left" and "away" variables nor any corresponding ratio was used for further analysis because, while gazes to the right were typically easy to identify based on minimal sclera visibility (pupil toward camera), distinguishing between "left" and "away" was, at times, a matter of guessing. The fact that "away" included looking slightly down with only minor change in sclera visibility combined with the poor video resolution rendered it impossible to retain scientific accuracy in this regard. Therefore, only the "right" attribute data was exported for statistical analysis in *IBM SPSS Statistics 22* (2013), where amount of total gazes at the distractor screen as well as their overall duration in frames (equals seconds) were computed. This yielded two major variables for self-control quantification: D_c (count of gazes at the right screen signifying distraction) and D_D (duration of gazes at the right screen signifying distraction). To check for coding reliability, four Anvil coding files were picked randomly and coded anew by the same researcher one week after initial coding: overall coding agreement, considering both

segmentation and categories, was calculated using a built-in function of the Anvil software and found to be consistently greater than 77% (see Table 1).

TABLE 1
INTRA-RATER RELIABILITY OF GAZE BEHAVIOR CODING IN *ANVIL*

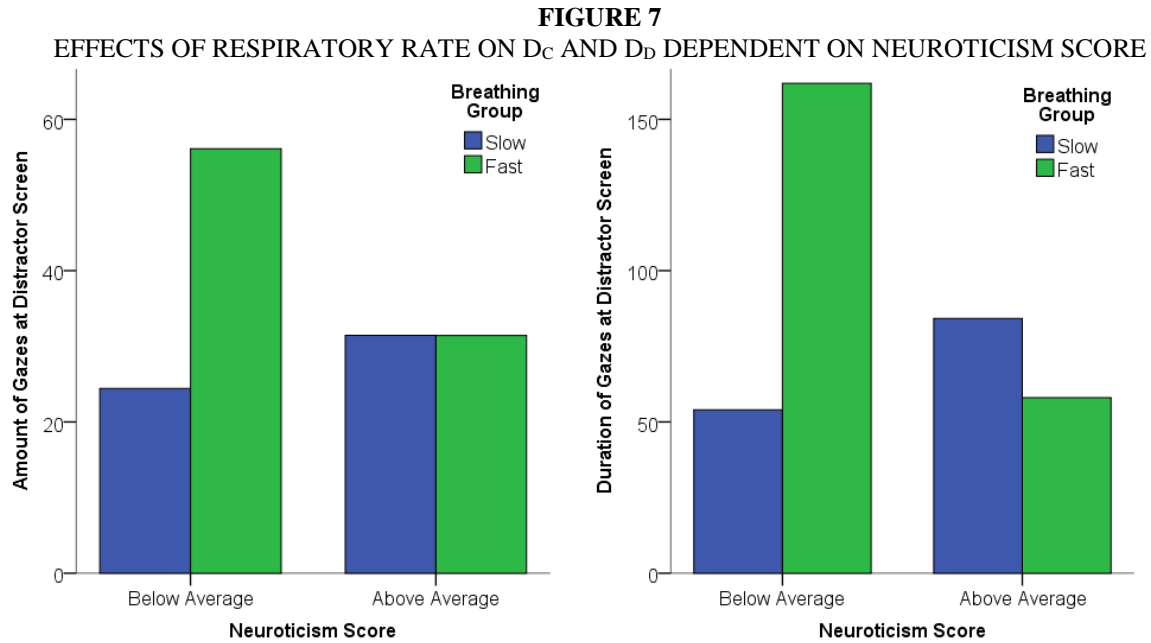
Subject #	Percentage	Cohen's Kappa	Corrected Kappa	Krippendorff's Alpha
206	78.66%	.4855	.6799	.4854
227	97.56%	.8699	.9634	.8702
212	77.50%	.5001	.6625	.5011
209	79.41%	.4108	.6912	.4101

Heart Rate Analysis. *Kubios HRV 2.2* (Tarvainen et al. 2014, <http://kubios.uef.fi/>) was used to calculate HRV based on RR interval data, which was extracted from the LabChart heartbeat data using Python algorithms: two 90-second segments for the breathing exercise part and two 180-second segments for the distraction task part of the experiment. Medium-level artifact correction was applied to 28 of the 176 files after discarding 12 files (= 3 subjects) due to faulty data content. Calculated HRV variables included, in the time-domain, SDNN (standard deviation of the normal-to-normal sinus-initiated inter-beat-intervals), RMSSD (root mean square of successive differences between normal heartbeats), lnRMSSD (natural logarithm of RMSSD), and PNN50 (proportion of the number of pairs of successive normal-to-normal inter-beat-intervals that differ by more than 50 milliseconds divided by total number of those intervals), and, in the frequency-domain, high-frequency power (HF 0.15-0.4 Hz), low-frequency power (LF 0.04-0.15 Hz), very-low-frequency power (VLF 0-0.04 Hz), total power, and LF/HF ratio. After the comparison of results, frequency-domain variables based on Fourier transformation (FFT) were preferentially chosen to those based on the autoregressive approach (AR), because the former yielded lower p values and had been found to be more applicable to short-term HRV than the latter (Chemla et al. 2005).

Variables. In summary, the experiment's dependent variables were recorded heart frequency, calculated HRV, coded gazes at the distractor screen, and counted food item uptake. The independent variable was respiratory behavior as instructed by the breathing exercise.

Results

Breathing Group. Gaze behavior was analyzed over both experimental rounds together and without gender segregation. This is due to the distraction variables D_C and D_D not significantly varying between the set of video clips displayed nor between sexes. An independent samples t-test revealed that subjects in the fast breathing group gazed more often ($n = 24$, $M = 41.17$, $SD = 21.71$) at the distractor screen (D_C) than subjects in the slow breathing group ($n = 23$, $M = 27.17$, $SD = 18.33$), as was revealed by an independent samples t-test ($t(45) = -2.38$, $p = .021$). A nonparametric test indicated that the total duration of those gazes (D_D), which was not normally distributed, was also longer in the fast breathing group ($M = 27.92$ s) than in the slow breathing group ($M = 19.91$ s; Mann-Whitney: $U = 182$, $p = .045$). In the slow breathing group, D_C ranged from 5 to 69 times and D_D from 6 to 353 seconds; in the fast breathing group, D_C ranged from 9 to 80 times and D_D from 10 to 384 seconds. This demonstrates that not a single subject was capable of refraining entirely from peeking at the more exciting video footage. The effects of breathing rate on D_C and D_D respectively were particularly distinct when subjects were grouped by neuroticism score. Only participants who scored below average in neuroticism were significantly more likely to get distracted if they had been instructed to breathe at a fast pace as compared to similarly emotionally stable participants in the slow breathing group (see Fig. 7 as well as Big Five-related result below).



Subject's D_C could be partially predicted by the time distance to their last meal consisting of at least 250 kcal ($R^2 = .350$, $F(1,36) = 5.020$, $p = .031$), indicating that they tended to have less willpower when their stomachs were emptier: D_C increased by an average of 1.2 gazes for every additional hour without food prior to the experiment. Participants who got distracted more often also tended to get distracted longer, as both distraction variables, D_C and D_D , were found to be positively correlated ($r(47) = .717$, $p < .001$). The ratio between these two variables was not significantly related to any other variables.

Questionnaire Items. Neither time of the day nor amount of sleep during the previous night (which predicted only chosen treadmill velocity: $R^2 = .462$, $F(1,16) = 9.775$, $p = .003$) nor caffeine or nicotine consumption prior to the experiment were found to have an impact on performance. Also, no significant relationships between performance on the one hand and leisure-time exercise, self-estimated performance, self-perceived self-control, or self-perceived distractibility on the other could be found. The latter three questionnaire items were highly interrelated though. Besides, 76.6% of subjects deemed their self-regulatory

strength to be above-average as compared to other people of their age group. After clustering subjects into groups of above-average and below-average leisure-time exercise scores, subjects with higher physical exercise levels had better self-reported self-control ($n = 13$, $M = 4.08$, $SD = .64$) than subjects who were less physically active ($n = 19$, $M = 3.58$, $SD = .51$; t-test: $t(30) = -2.452$, $p = .02$).

Personality Traits. The 25 items of the Big Five questionnaire were subjected to a factor analysis. A five-factor solution (one component for each personality trait) explained 62.18% of total variance ($KMO = .552$). The traits extraversion, openness, agreeableness, and conscientiousness were not significantly related to any other variables, except that more extroverted women perceived themselves as more distractible ($r(19) = .574$, $p = .010$) and found the executive-function task to be more difficult ($r(25) = .491$, $p = .013$). Neuroticism was more prominent among females (t-test: $t(44) = -3.78$, $p < .001$ (males: $n = 21$, $M = -.61$, $SD = .96$; females: $n = 25$, $M = .40$, $SD = .85$)). Neuroticism score was a partial predictor of both D_C ($R^2 = .449$, $F(1,21) = 17.088$, $p < .001$) and D_D ($R^2 = .313$, $F(1,21) = 9.581$, $p = .005$) only in the fast breathing group, not in the slow one. Within the group of fast breathers, subjects with lower neuroticism score tended to be more distractible later in the experiment than those scoring higher in neuroticism: for every additional unit in neuroticism score, their gaze at the right screen decreased by 13 in amount and by 46 seconds in duration according to the model. Greater neuroticism correlated, again only in the fast breathing group, with more stress experienced during the experiment ($r(23) = .661$, $p = .001$); a variable that did not significantly differ between groups but was correlated over all groups with how difficult participants rated the attentional control task ($r(47) = .569$, $p < .001$). Perceived task difficulty correlated negatively with time distance to the last eaten meal ($r(38) = -.391$, $p = .015$) and positively with self-estimated distraction during the task ($r(38) = .499$, $p = .001$) as well

as with general self-perceived distractibility ($r(40) = .373, p = .021$), which was, once more, correlated with neuroticism ($r(37) = .430, p = .008$). In the fast breathing group, self-estimated distraction correlated with experienced stress ($r(18) = .576, p = .012$), while there was no such relationship in the slow breathing group.

Ego Depletion. Men, but not women, who believed in ego depletion experienced more stress during the experiment ($n = 11, M = 2.27, SD = .64$) than men who did not share this belief ($n = 8, M = 1.38, SD = .52$; t-test: $t(17) = 3.24, p = .005$). However, the belief that willpower is a limited resource, which was maintained by 51.1% of subjects, was not found to have a significant effect on executive control performance. Nor were D_C and D_D respectively in any way associated with the type or amount of food items consumed during the questionnaire round after the behavioral experiment. The only related finding was that the total amount of calories consumed correlated positively with age ($r(46) = .351, p = .017$) and leisure-time exercise ($r(35) = .713, p < .001$): people who consumed higher calorie reward snacks tended to be older and more physically active in their spare time.

Cardiological Measurements. Mean heart rate during the experiment ranged from 76.49 to 106.53 beats per minute in males ($M = 94.56$ bpm, $SD = 8.45$ bpm) and from 71.60 to 138.56 bpm in females ($M = 99.24$ bpm, $SD = 15.89$ bpm). It was lower in subjects who reported regular practice of Yoga or meditation ($n = 5, M = 84.46$ bpm, $SD = 6.93$ bpm) in comparison to the majority of subjects who did not ($n = 39, M = 98.61$ bpm, $SD = 12.71$ bpm; t-test: $t(42) = 2.426, p = .02$). Heart rate correlated negatively with amount of calories consumed afterwards ($r(43) = -.406, p = .007$) as well as with leisure-time activity score ($r(35) = -.533, p = .001$). HRV did not significantly depend on age (which had a notably narrow range) nor sex, with exception to mean LF/HF ratio, which correlated positively with age ($r(44) = .307, p = .043$). The small group of smokers ($n = 5$) in the sample did not

have exceptionally different HRV values from non-smoking subjects ($n = 42$), despite smoking previously having been found to reduce HRV (Rajendra Acharya et al. 2006). Thus, smoking was not corrected for in the analysis of this experiment. No significant changes in HRV over time, i.e., between the two experimental rounds, could be found. T-test results comparing different mean measures of HRV during breathing exercise and executive-function task (see Table 2) indicate that the slow breathing exercise tended to elevate HRV while the fast breathing exercise had an opposite effect, especially in the LF band.

TABLE 2
MEAN HRV DURING BREATHING EXERCISE AND DISTRACTION TASK

HRV	Group	M (SD) Breathing	M (SD) Distraction	df	t	p
RMSSD	Slow	28.00 (14.10)	26.97 (27.28)	64.46	.222	.824
	Fast	20.22 (10.43)	23.86 (10.58)	85.98	-1.624	.108
SDNN	Slow	59.04 (23.92)	34.13 (19.95)	83.31	5.304	<.001
	Fast	29.81 (12.22)	36.53 (13.95)	84.53	-2.403	.018
PNN50	Slow	7.06 (6.53)	7.00 (13.81)	61.30	.026	.979
	Fast	3.84 (5.53)	6.18 (7.91)	76.89	-1.607	.112
HF Power	Slow	406.13 (548.18)	301.39 (574.07)	87.81	.885	.378
	Fast	271.36 (253.63)	209.20 (212.19)	87.28	1.275	.206
LF Power	Slow	2551.71 (2122.49)	490.98 (546.24)	49.80	6.307	<.001
	Fast	336.62 (397.32)	642.52 (578.79)	79.70	-2.955	.004
LF/HF Ratio	Slow	11.15 (8.32)	5.69 (6.51)	81.33	3.435	.001
	Fast	2.13 (2.88)	5.52 (5.29)	66.56	-3.740	<.001

RMSSD...root mean square of successive differences between normal heartbeats; SDNN...standard deviation of the normal-to-normal sinus-initiated inter-beat-intervals; PNN50...proportion of the number of pairs of successive normal-to-normal inter-beat-intervals that differ by more than 50 milliseconds divided by total number of those intervals; HF Power...high-frequency power (0.15-0.4 Hz) based on Fourier transformation; LF Power... low-frequency power (0.04-0.15 Hz) based on Fourier transformation; LF/HF Ratio...ratio of low-frequency power to high-frequency power.

Mean LF/HF ratio during the distraction task correlated negatively with self-reported self-control ($r(38) = -.341$, $p = .036$). The ANOVA results in Table 3 demonstrate the group differences in the strength of HRV measurements to predict D_C .

TABLE 3
RESULTS OF REGRESSING D_C ON HRV DURING DISTRACTION TASK

HRV	Group	R ²	F(1,20)	p
lnRMSSD	Slow	1233.964	4.008	.059
	Fast	214.546	.442	.514
SDNN	Slow	1366.929	4.539	.046
	Fast	525.660	1.119	.303
Power	Slow	1445.978	4.865	.039
	Fast	1.373	.003	.959
LF/HF Ratio	Slow	1745.146	6.183	.022
	Fast	282.236	.755	.395

lnRMSSD...natural logarithm of RMSSD; SDNN...standard deviation of the normal-to-normal sinus-initiated inter-beat-intervals; Power...frequency-domain total power based on Fourier transformation; LF/HF Ratio...ratio of low-frequency power to high-frequency power.

In the slow breathing group, D_C decreased by .421 for every additional millisecond in SDNN, by .007 for every additional ms^2 in total absolute power, and increased by 1.476 for every additional unit in LF/HF. D_D was found to be predictable only by LF/HF ratio in the slow breathing group ($R^2 = 64137.210$, $F(1,20) = 11.425$, $p = .003$): it increased by 8.948 seconds for every additional unit in LF/HF. Also during the distraction task, SDNN/RMSSD ratio, a suggested surrogate for LF/HF (Wang & Huang 2012), was significantly higher for subjects who scored below average in leisure-time exercise ($n = 12$, $M = 1.86$, $SD = .45$) than for above-average subjects ($n = 8$, $M = 1.40$, $SD = .25$; t-test: $t(18) = 2.619$, $p = .017$) but only in the fast breathing group.

Discussion

Main Hypothesis. The results support my main, hitherto uninvestigated hypothesis: brief, paced breathing has a short-term effect on willpower. In particular, slow-paced breathing tends to influence attentional impulse control performance on a subsequent executive-function task more favorably than fast-paced breathing. Another possible interpretation, however, could arise from congruence between the physiological state and situational context of an organism on the one hand, and its breathing on the other. An example of this would be slow breathing in consistence with slow walking; higher congruence affects self-regulatory strength more positively, or less negatively, than lower congruence in breathing patterns. In further studies, this could be tested by introducing a systematic variation of treadmill velocities as an additional independent variable.⁴ Furthermore, different types of willpower challenges might call for different breathing patterns: when jumping out of a helicopter, swimming under ice, avoiding heroin as an addict, resisting chocolate, doing a water fast, focusing on writing a paper despite a dozen good reasons to procrastinate, or not getting distracted by attention-grabbing video clips—self-control may be affected quite differently by the same respiratory rate in different situations. The present study cannot draw conclusions about the potential task-dependency of the investigated effect.

Personality. Contrary to expectation, conscientiousness did not prove to be an index of willpower in the form of attentional impulse control, even though this Big Five trait is typically characterized, among other factors, by self-control (Green et al. 2015). This might be

⁴ If subjects have to focus too much on their movement, however, which they will if they must move at a velocity they are not accustomed to, then this might artificially alter the perceptual effect of the distractive stimuli.

due to the fact that laboratory tasks set objectives that are not rooted in the participants' personal goals. Personal goals are crucial for self-discipline and since the experiment did not provide any incentive to do well at the distraction task, a potential lack of motivation cannot be excluded. Nevertheless, there is no reason to assume that any lack of motivation was systematic: a potential group bias in willingness to conform to the experimenter's command—i.e., obedience, which was been related to high scores in conscientiousness and agreeableness (Bègue et al. 2015)—is not supported by the Big Five results. The same reasoning applies to the factor of curiosity: unsettling auditory stimuli will trigger more desire to visually experience what is happening in some subjects than in others. Again, the trait that characterizes such curiosity, namely openness to experience, was in no way significantly related to relevant variables. Also, the age range was not broad enough to have a confounding impact in this regard. It might further be objected that nothing much is actually happening and that subjects are aware that the content of the video clips has no immediate relevance to them—yet despite the artificial laboratory environment, participants invariably failed to entirely refrain from looking at the distractor (as D_C was never nil).

Neuroticism. The finding that neuroticism was more prevalent in women is in line with the consensus in psychology (e.g., Schmitt et al. 2008). On the other hand, that higher neuroticism scores were associated with greater self-regulatory resistance against distraction demands explanation for the reason that, contrary to the results of this experiment, neuroticism is commonly associated with impulsiveness, poor response to stressors, and weakness in controlling urges (Bhagat & Nayak 2014). Moreover, Geisler & Kubiak (2009) claim that neuroticism is negatively related to self-control. Since the peculiar finding in dispute was statistically significant only in the fast breathing group, one potential explanation could be

that a high breathing frequency resonates better with people who score highly in neuroticism, as these people tend to have greater activity in brain areas associated with sympathetic control (Schultz & Schultz 2013). This would support the congruent breathing hypothesis mentioned above. However, sympathetic activity should be reflected at least to some degree in HRV variables, for example, LF power during rapid breathing. Since these variables did not correlate with neuroticism, that explanation is dubious. Another explanation for why more neurotic subjects tended to get less distracted could be that they were more anxious to follow the experimental instructions correctly or that they wanted to prevent the feeling of failing at the given task in the presence of two experimenters. Neurotic people have heightened emotional reactivity to such negative emotions (Larsen & Ketelaar 1989), and the stress associated with rapid breathing, which more neurotic subjects did indeed report to having experienced more acutely, might have intensified these emotions and thus led to less gazes at the distractor screen. In which case, those gazes would, in fact, be a poor measure of willpower or attentional impulse control, rather to the contrary. The second explanation, however, does not allow for the fact that the desire to complete a task well characterizes conscientiousness, which was no significant partial predictor of distracted gazes. Furthermore, the second hypothesis would have predicted an additional corresponding difference in the slow breathing group; this was not reflected in the results. The third, most promising explanation is again in line with the congruent breathing hypothesis, claiming that the stress induced by the rapid breathing exercise created an environment in which more neurotic subjects could function better than more emotionally stable ones. This hypothesis is encouraged by Smillie and colleagues (2006), who found that in a busy work environment highly neurotic individuals tended to outperform their stable counterparts.

Psychostimulants. Contrary to most studies (Einöther & Giesbrecht 2013), caffeine intake was not associated with visual executive control performance. This correlational absence might be a result of the limited questionnaire data that did not specify self-administered dosage. Brunyé et al. (2010) found solely their highest administered dose of 400 mg of caffeine to produce significant effects on executive control. Furthermore, the present study's measurement of attentional executive control was not based on conventional, standardized methods like, for example, the attention network task (e.g., Fan et al. 2002) or the rapid visual information processing task (e.g., Bakan 1959). Lastly, individual caffeine consumption profiles and respective tolerance levels were not taken into consideration. Despite the same limitations holding for nicotine and with the amount of smokers in the sample being unevenly small, the absent correlation between nicotine consumption and executive attention does not contradict the results of Myers et al. (2013), which are, however, not representative of the general scientific consensus on the enhancing effects of nicotine on cognitive performance (Heishman et al. 2010).

Heart Rate Variability. Physiologically, the two breathing exercises had disparate effects on HRV. Compared to the unguided, spontaneous breathing during the distraction task, HRV was clearly decreased during the rapid breathing exercise and clearly increased during the slow breathing exercise, especially in the LF band. This complies with the well-researched phenomenon of RSA. However, temporal limitations of the experiment allowed no HRV baselines and only brief segments of RR intervals (90 and 180 seconds respectively) to be recorded. Therefore, the HRV data bears only minor validity and must be interpreted with caution. Direct comparisons to the results of Segerstrom and Solberg Nes (2007) or Reynard and colleagues (2011) are not applicable, all the more so due to my experiment not conforming to an ego depletion design. Besides, different HRV epoch lengths

should never unsystematically be compared in the first place due to the length of the recording having large effects on HRV values (McCraty & Shaffer). Nonetheless, HRV during the self-control task linearly predicted, in both time and frequency domain, executive control performance in such a way that it was elevated upon every increase in SDNN or total power. Thus, higher HRV seems indeed to reflect greater self-regulatory strength. That the regressions on RMSSD and lnRMSSD respectively were not quite significant ($p = .070$ and $.059$ resp.) as compared to the regression on SDNN ($p = .046$) is surprising given the short duration (2x3 minutes) of the respective HRV recordings. Being a short-term variation of heart rate (Wang & Huang 2012), (ln)RMSSD is typically the preferred HRV measure for short-term or even ultra-short-term durations (Esco & Flatt 2014). However, SDNN's correlation to LF power (Wang & Huang 2012) might explain why precisely slow breathers' performance was predicted by SDNN rather than RMSSD. This leads to the next issue concerning the general group dependency of the regression results: they pertained only to the slow breathing group, for in the fast breathing group regressions of distractor variables on HRV were consistently insignificant. This might be due to the fact that in short-term SDNN, the parasympathetic nervous system mediates the primary source of variation, especially with slow, deep breathing patterns (McCraty & Shaffer 2015). RMSSD, on the other hand, correlates with HF power, which in the present study did not significantly vary between groups nor parts of the experiment—hence less latitude for significant predictions after rapid breathing. Lastly, the only HRV variable that could predict both D_C and D_D in the slow breathing group was the LF/HF ratio. In the face of the tendency of slow respiration rates to prompt vagal activity to reach into the LF band, an increased LF/HF ratio would here indicate parasympathetic dominance, whereas typically it would not. However, as the hypothesis that the LF/HF ratio reflects sympatho-vagal balance has been disproven (Billman

2013), it is unclear what this measure factually represents. I will therefore withhold interpretations on this ratio's role in predicting self-regulatory strength. Still, the significant regression results suggest that LF/HF ratio may be of value in further research after all. In summary, the cardiological results partially support the view that HRV has a mediating or mechanistic role in the way respiration affects attentional impulse control. On the one hand, HRV did not differ significantly between groups after the guided breathing exercise, indicating that RSA-based changes in HRV counterbalanced as soon as subjects could breathe at their own pace again. On the other hand, a short-term impact of slow breathing on willpower was still found to be reflected in some HRV measures. Finally, it must be taken into consideration that the experimental design, particularly the aggressive auditory stimulation during the distraction task, most probably influenced HRV not just due to the inherent situational stress but additionally because of the impact even simple visual and acoustic stimulation has on HRV (Hatzl 2012).

Ego Depletion. The lack of correlation between subjects' beliefs in ego depletion and willpower performance fails to replicate the results of other studies that claim a negative effect of implicit limited-resource theories on self-regulation (Job et al. 2015, Job et al. 2010). First and foremost, it must be taken into account that the present study inquired upon belief in ego depletion by solely one questionnaire item with the options "yes", "no", and "don't know", and this post-task inquiry did not prime subjects in the same way they were primed with directing beliefs in the other studies. Furthermore, the present study was not structured to investigate ego depletion, which would have required a control group of subjects who did not perform a self-control task. This was not the aim of the present experiment. On the other hand, the dynamics of self-regulatory fatigue are undoubtedly present in every

situation that demands self-regulatory effort. An investigation of whether the breathing exercise would affect such fatigue in general rather than merely attentional control in particular was attempted by offering reward snacks posterior to the self-regulation task and counting which and how many would be consumed. The lack of correlation between food item uptake with either breathing group or attentional control performance may indicate three things. First, self-control could be less monolithic than presumed by this study and might thus not have been challenged uniformly by the distraction task and the food reward. Second, the brief breathing exercise might not have been sufficient to yield longer-lasting effects—for the snack was offered more than five minutes after the last breathing exercise, compared to the executive-function task which followed within a few seconds without artificial distractions. Third, calorie consumption might have simply been too dependent upon too many uncontrollable factors, even though the most important ones were allowed for by the questionnaire.

Self-Assessment. The finding that self-reported self-control was not at all an indicator of behavioral self-control suggests that at least one of these measures must have been inaccurate. The self-report data seems to be unreliable, next to the common issue of cognitive biases, considering that subjects tended to statistically overestimate their own self-regulatory strength relative to others—yet this could also be a demographic artifact of the sample composition. The behavioral analysis of self-control too has limited accuracy. The behavior coding was completed by just one researcher with moderate intra-rater reliability. Eye tracking would have warranted a more reliable and more nuanced analysis of gaze behavior than manual frame-by-frame coding of video material but the experimental design rendered this technology non-viable. Moreover, eye motion in general was at best a partial indicator of attention, for paying attention to the distracting auditory stimuli or even looking somewhere

else entirely was not counted as an instance of distraction as long as subjects' gaze behavior did not evince an overt shift in visual attention toward the distractor screen. These methodological shortcomings are reinforced by the fact that no significant association between attentional control performance and leisure-time exercise scores could be found. This is problematic in the face of numerous studies unanimously suggesting such a relationship (Mullen & Hall 2015, Buckley et al. 2014, Kinnunen et al. 2012, Chaddock et al. 2010, Colcombe & Kramer 2003, Sibley & Etnier 2003). In agreement with these studies is the current experiment's finding that participants who were more physically active in their leisure time also had greater self-assessed self-control. While this could merely mean that people who exercise more are likely to perceive themselves as having more willpower than others, it might well suggest that the current study's measure of behavioral self-regulation is the methodologically more precarious link.

Further Limitations. The experimental context had subjects walk on a treadmill, in addition to the pre-exhaustion caused by the prior experiment. This must not be disregarded when interpreting the results, especially since physical effort has an impact not only on HRV (e.g., Perini & Veicsteinas 2003) but on the correlation between HRV and cognitive performance as well (Luft et al. 2009). However, this problem is alleviated by at least three facts. First, the physical effort of walking slowly was the same for all subjects. Second, the individually chosen treadmill velocity correlated with neither performance nor HRV. Finally, it can be argued, from an evolutionary point of view, that the experimental setting of walking actually bears less artificiality compared to that of sitting. A more problematic limitation of the present study is that sample size calculations rendered it unwise to include a control group of subjects who would not be instructed to perform a breathing exercise but would breathe spontaneously instead. Therefore, the results do not imply that slow breathing is in

any sense superior to normal, unregulated respiration. Further research should consider including an unguided breathing group, along with a more systematic variation of multiple respiration rates and a physiological measurement to correct for actual respiratory performance. Maybe individually adjusted respiration rates, relative to each subject's own baseline, would yield even more meaningful results. Another limitation is, of course, the short duration of the breathing exercise; although this, on the other hand, renders the results collected only more impressive. Future research could systematically vary this factor as well or test the hypothesis by means of other impulse control tasks—also to investigate the homogeneity of self-control dynamics under different willpower challenges, as mentioned above. Lastly, in order to get a more comprehensive understanding of the underlying mechanisms of the relationship between breathing and self-control, the factor of emotional regulation should be controlled for as well, namely by measuring potentially mediating affective processes. In particular, one question remains ultimately undecided: did slow breathing increase willpower, which was in turn used to manage stress and emotions, or did it regulate stress and emotions, thus lessening willpower demands? My finding of experienced stress during the distraction task not significantly differing between breathing groups suggests the former hypothetical causal nexus.

Cognitive Science. As far as interdisciplinarity is concerned, my study integrated established methods from anthropology (video recording and nonverbal behavior analysis via motion coding), psychology (executive-function task and questionnaire data), as well as physiology (cardiac frequency and heart rate variability). From an embodied cognition perspective, it is interesting to see the possibility reinforced that cardiac rhythms reflect the functioning of cognitive control processes, namely the capacity to self-regulate behavior through prepotent response inhibition, and that both are sensitive to the body's respiratory

movements. Besides theoretical interests, experimental support for the main hypothesis that certain breathing patterns facilitate or impede executive functioning can be valuable for the practical interests of educators, body-oriented psychotherapists, HRV biofeedback practitioners, self-development coaches, and therapists dealing with executive function disorders.

Conclusion. On any given day, everyone faces his or her very personal willpower challenges. While each unique challenge can only be mastered through mindfulness and self-discipline, the positive results of this study can be combined under the following insight: if a task demands (attentional) self-control, you might find it helpful to mindfully modulate your breathing rate, to prepare yourself with proper⁵ nutrition, and to be aware of your personality traits and how they might lead you to interact with your environment.

⁵ What proper nutrition should consist of, let alone in each individual case, cannot be answered by this study, which solely found having an emptier stomach to be a weak general indicator or poorer self-control performance. This finding implies nothing with regards to nutritional quality, a linear relationship to different levels of fullness, dietary lifestyles, etc., nor does it take into account various other crucial factors such as, for instance, individual mental and physiological adjustment to fasting. Nonetheless, it does suggest that the energy gained from food is an influencing factor.

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Appendices

Appendix A: 25-Item Big Five Inventory.



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Teilnehmernummer:

Bewerten Sie bitte die folgenden Aussagen anhand der Skala: Der **erste Kreis** bedeutet, dass diese Aussage Ihrer Meinung nach **überhaupt nicht** auf Sie zutrifft, der **letzte Kreis** bedeutet, dass sie **völlig** auf Sie zutrifft. Mit den Kreisen dazwischen können Sie Ihre Meinung abstimmen. Wir bitten Sie, den Fragebogen zur Gänze und gewissenhaft auszufüllen.

Ich sehe mich als jemand der ...	Trifft überhaupt nicht zu					Trifft völlig zu		
... zurückhaltend ist.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
... eher ruhig ist.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
... kommunikativ, gesprächig ist.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
... einfallsreich ist.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
... eher unorganisiert ist.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
... eher faul ist.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
... aus sich herausgehend, gesellig ist.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
... sich manchmal gehemmt fühlt, schüchtern ist.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
... gern reflektiert, mit Ideen spielt.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
... eine lebhafte Fantasie/Vorstellung hat.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
... künstlerische, ästhetische Erfahrungen schätzt.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
... originell ist, neue Ideen einbringt.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
... gründlich arbeitet.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
... Aufgaben wirksam und effizient erledigt.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
... bis zum Ende einer Aufgabe durchhält.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
... sich oft Sorgen macht.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
... entspannt ist, mit Stress gut umgehen kann.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
... angespannt sein kann.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
... leicht nervös wird.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
... nicht leicht aus der Ruhe zu bringen ist.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
... manchmal etwas grob zu anderen ist.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
... kalt und distanziert ist.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
... Streit anfängt.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
... rücksichtsvoll und freundlich mit anderen umgeht.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
... verzeihen kann.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Appendix B: Post-Task Questionnaire.

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Teilnehmernummer:
Datum und Uhrzeit:
Exp

Fragebogen

Wir bitten Sie, den folgenden Fragebogen zur Gänze und gewissenhaft auszufüllen. Sollten Sie auf eine/mehrere Fragen dezidiert nicht antworten wollen, bitten wir Sie, diese Frage(n) zu überspringen und zur nächsten Frage überzugehen. Danke!

1) Alter: _____ Jahre

2) Geschlecht: ☐ männlich ☐ weiblich

3) Sexuelle Orientierung: ☐ hetero ☐ bi ☐ homo

4) Wie gut sprechen Sie Deutsch? ☐ Anfänger (A1/A2)
☐ Basis-Kenntnisse (B1/B2)
☐ Fortgeschritten (C1/C2)
☐ Niveau entspricht etwa Muttersprache

Wie gut sprechen Sie Englisch? ☐ Beginner (A1/A2)
☐ Basic (B1/B2, etwa Maturaniveau)
☐ Advanced (C1/C2)
☐ Native Speaker

5) Woher stammen Ihre Eltern?

Mutter: <input type="checkbox"/> aus Westeuropa	Vater: <input type="checkbox"/> aus Westeuropa
<input type="checkbox"/> aus Zentraleuropa	<input type="checkbox"/> aus Zentraleuropa
<input type="checkbox"/> aus Süd-/ Osteuropa	<input type="checkbox"/> aus Süd-/ Osteuropa
<input type="checkbox"/> außerhalb Europas	<input type="checkbox"/> außerhalb Europas

6) Höchster Schulabschluss: ☐ Hauptschule ☐ BMS ☐ Matura
☐ BSc/BA ☐ Mag./MSc/MA ☐ Dr./PhD

7) Studienrichtung: _____ ☐ keine

8) Haben Sie derzeit eine bewegungsbeeinträchtigende Verletzung?

Körperstelle: _____ ☐ nein

9) Ist Ihr Bewegungsapparat eingeschränkt oder leiden Sie unter chronischen körperlichen Schmerzen?

Körperstelle: _____ ☐ nein



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Teilnehmernummer:
Datum und Uhrzeit:
Exp

10) Hatten Sie jemals Hand-/Fingerbrüche?

linke Hand: ☐ ja, am _____ Finger, vor _____ Jahren ☐ nein

rechte Hand: ☐ ja, am _____ Finger, vor _____ Jahren ☐ nein

11) Leiden Sie derzeit an einer Infektion? (Grippe, Erkältung, Schnupfen, Entzündung, etc.)

☐ ja, an _____ seit _____ Tagen ☐ nein

12) Welche der folgenden psychotropen Substanzen haben Sie in den letzten 6 Stunden konsumiert?

- ☐ Koffein
- ☐ Nikotin
- ☐ Alkohol
- ☐ stärkere Stimulanzien (Amphetamine, Kokain, etc.)
- ☐ Sedativa (Marihuana, Kratom, Benzodiazepine, etc.)
- ☐ Halluzinogene (Psilocybin, LSD, Mescaline, Ketamin, etc.)

13) Welche der folgenden Medikamente nehmen Sie regelmäßig ein?

- ☐ Herz-Kreislauf-Medikamente
- ☐ ADHS-Medikamente (z.B. Ritalin)
- ☐ Antiasthmatica
- ☐ Antidepressiva
- ☐ Anabolika

14) Wie fit fühlen Sie sich heute? ☐ sehr ☐ etwas ☐ wenig ☐ gar nicht

15) Wie lange haben Sie letzte Nacht geschlafen? _____ Stunden

16) Wie lange liegt Ihre letzte größere Mahlzeit (mehr als 250 kcal) zurück? _____ Stunden

17) Wie wichtig ist es Ihnen, sich gesund zu ernähren? ☐ sehr ☐ etwas ☐ wenig ☐ gar nicht

18) Wie *selbstkontrolliert* schätzen Sie sich persönlich ein, verglichen mit anderen Personen Ihrer Altersgruppe? ☐ viel besser ☐ besser ☐ mittelmäßig ☐ schlechter ☐ viel schlechter

19) Wie *ablenkbar* schätzen Sie sich persönlich ein, verglichen mit anderen Personen Ihrer Altersgruppe?

- ☐ viel mehr ☐ mehr ☐ durchschnittlich ☐ weniger ☐ viel weniger

20) Wie sehr haben Sie sich beim zweiten Experiment vom anderen Bildschirm ablenken lassen?

- ☐ oft & lange ☐ oft, nicht lange ☐ lange, nicht oft ☐ weder oft noch lange ☐ nie



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Teilnehmernummer:
Datum und Uhrzeit:
Exp

21) Wie schwer ist es Ihnen gefallen, sich nicht ablenken zu lassen?

☐ sehr schwer ☐ schwer ☐ leicht ☐ sehr leicht

22) Wie gestresst haben Sie sich beim zweiten Experiment gefühlt?

☐ sehr ☐ etwas ☐ wenig ☐ gar nicht

23) Glauben Sie, dass Willenskraft eine erschöpfbare Ressource ist?

☐ ja ☐ nein ☐ weiß nicht

24) Praktizieren Sie regelmäßig ...

... Meditation? ☐ ja, etwa ____ Std./Woche ☐ nein

... Yoga? ☐ ja, etwa ____ Std./Woche ☐ nein

... Atemübungen? ☐ ja, etwa ____ Std./Woche ☐ nein

25) Innerhalb einer gewöhnlichen Woche, wie oft üben Sie folgende Aktivitäten *für mehr als 15 Minuten* in Ihrer Freizeit aus?

☐ sehr anstrengende Aktivität (z.B. Kraftsport, Kampfsport, fordemder Ballsport, Schwimmen, langes Radfahren, schnelles Laufen) ____ Mal pro Woche

☐ mäßig anstrengende Aktivität (z.B. schnelles Gehen, Joggen, Tennis, Volleyball, Federball, Frisbee, Tanzen, einfaches Radfahren) ____ Mal pro Woche

☐ wenig anstrengende Aktivität (z.B. Dehnen, Yoga, Fischen, Bowling, Billard, Golf, Spazieren) ____ Mal pro Woche

26) Innerhalb einer gewöhnlichen Woche, wie oft sind Sie körperlich so aktiv, dass Ihr Herz schnell schlägt und Sie schwitzen müssen?

☐ oft ☐ manchmal ☐ nie

Appendix C: Form of Consent.

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Department für Anthropologie
Althanstraße 14
1090 Wien

Einverständniserklärung

Sie haben an der psychophysiologischen Studie „Motion-Emotion, Breathing-Willpower“ der Universität Wien teilgenommen. Die dabei gesammelten Daten werden unter Wahrung des Datenschutzgesetzes ausschließlich zu wissenschaftlichen Zwecken verwendet und weder veröffentlicht noch an Dritte weitergegeben.

Ich, _____ bestätige hiermit, freiwillig an dem
Vorname Nachname
 Experiment teilgenommen zu haben sowie über Wesen und Bedeutung der Studie aufgeklärt worden zu sein. Ich gebe mein Einverständnis, dass meine Daten der Universität Wien für wissenschaftliche Zwecke zur Verfügung stehen.

 Ort, Datum

 Unterschrift

Falls Sie über die Resultate dieser Studie informiert werden möchten, können Sie hier optional

Ihre E-Mail-Adresse angeben:

Appendix D: Laboratory Instructions.

I) Sitzungsvorbereitung

1. Computer & Monitore vorbereiten
 - a. PL PC: *VEP_ANNA* öffnen
 - b. DN PC (wenn gerade neu gestartet): Befehl in *restart_timeserver.rtf* in Shell ausführen
 - c. DN PC: Anleitung.pdf folgen
2. gruppenspezifisches Videofile 2x in *movies* kopieren
3. Trinkwasser vorbereiten
4. Clipboards vorbereiten (Stroop & PAD)
5. Fragebogenraum vorbereiten
 - a. frisches Glas Wasser
 - b. 4 Schokoriegel (je 1 pro Sorte)
 - c. 4 Früchteriegel
 - d. 2 Reiswaffeln mit Salz
 - e. 2 Reiswaffeln mit Schokolade
 - f. 2 Energy Drinks (1 mit, 1 ohne Zucker)
 - g. 3-seitiger & BigFive Fragebogen (Teiln.nr. eintragen!) + Kugelschreiber
6. Laborjournal-Eintrag beginnen

II) Teilnehmervorbereitung

1. Handscanner (free4me) → Bilder umbenennen
2. Waage → Gewicht eintragen
3. Körperhöhe → eintragen
4. Herzratengürtel
5. Schuhe, Atemgürtel & DiverNet → aufs Laufband
6. DN PC: Aufnahmestartbefehle ausführen → Modellcheck
7. T-Posture-Foto von vorne & hinten
8. Stroop-Test erklären & Probedurchlauf
9. Laufbandgeschwindigkeit wählen lassen & eintragen

III) Erstes Experiment

1. Licht aus
2. VEP PC: *VEP START* öffnen → Kamerabild → „s“
3. PL PC: *START REC.* → „tief einatmen“ → Range anpassen
4. „bereit?“ → VEP PC: *START*
5. VEP PC: Video → *PAUSE*
 - a. Laufband aus
 - b. T-Posture
 - c. PAD-Fragebogen (& Wasser anbieten)
6. VEP PC: *QUEST*
 - a. DN PC: „ctrl+c“ in beiden Shells
 - b. Stroop-Test: „los“ → VEP PC: *BUTTON*

- c. DN PC: Aufnahmestartbefehle ausführen
- d. „fertig“ → VEP PC: *BUTTON*
7. VEP PC: *NEXT*
 - a. T-Posture
 - b. Laufband ein → zurück zu Schritt 5 (6x)
8. VEP PC: *END* → „ctrl+c“ in Shell
9. DN PC: „ctrl+c“ in beiden Shells
10. PL PC: File → Save As
 - a. LabChart Data in Ordner „Anna“
 - b. Chart Data as Text in Ordner „Anna“

IV) Zweites Experiment

1. Licht an
2. DN PC: Aufnahmestartbefehle ausführen
3. PL PC: *VEP_ANNA* öffnen → *START REC.* → Rangecheck
4. VEP PC: *Durchgang 1* öffnen → Kamerabild → „s“
5. SERVER PC: *1 START* öffnen
6. T-Posture
7. Laufband ein
8. VEP PC: *START*
9. SERVER PC: *CONNECT SERVER*
10. VEP PC: *END* → „ctrl+c“ in Shell
11. SERVER PC: „ctrl+c“ in Shell
12. DN PC: „ctrl+c“ in beiden Shells
13. PL PC: File → Save As
 - a. LabChart Data in Ordner *Dom1*
 - b. Chart Data as Text in Ordner *Dom1*
14. Laufband aus
15. T-Posture
16. wiederhole Schritte 2-15 (mit *Durchgang 2, 2 START* & Ordner *Dom2*)
17. Proband befreien

V) Nachbereitung

1. zu Snacks & Fragebögen in anderen Raum
2. DiverNet entwürrn, alles reinigen, 3x *counter.txt* checken
3. Aufklärung über Hypothesen & Videokamera → Einverständniserklärung
4. Geldübergabe → Geldannahmebestätigung
5. Mahnrede („bitte nichts weitererzählen...“) → Verabschiedung
6. Snacks zählen → Laborjournal-Eintrag abschließen

Appendix E: Advertisement Poster for Subject Recruitment.

**Einladung zu
psychophysiologischem
Experiment**

Videoclips ansehen
während wir Bewegung, Atmung und Herzschlag messen
5 € verdienen
und einen kleinen Snack
+ Erfahrungsgewinn

(Abbildung kann von Experimentbedingungen abweichen.)

Voraussetzung: Alter 18-40
Ort: UZA I, Anthropologie, Kleiner Seminarraum
↳ Althanstraße 14, 1090 Wien
Termine: Montag-Sonntag, 10:00-20:00
↳ Dauer: 60-80 Minuten
Kontakt: exp.uza@gmail.com, 0699-12253614

 /exp.uza  Department of
Anthropology
University of Vienna  universität
wien  MEi: CogSci

Zusammenfassung

Herzratenvariabilität (HRV) liefert einen Index für Selbstkontrolle (Segerstrom & Solberg Nes 2007). Da Atemfrequenz einen Einfluss auf HRV hat (Song & Lehrer 2003), lässt sich die Hypothese aufstellen, dass Atmung Selbstkontrolle beeinflusst. Dieser Zusammenhang ist bisher noch nicht direkt untersucht worden. Die gegenwärtige experimentelle Studie hat die Hypothese getestet, dass sich bestimmte Atemmuster unmittelbar und kurzfristig auf die menschliche Fähigkeit auswirken, Ablenkungen durch Impulskontrolle zu widerstehen. Im Experiment führten 50 Teilnehmer eine kurze entweder langsame oder schnelle Atemübung durch und wurden anschließend aufgefordert, ihre Aufmerksamkeit auf einen Bildschirm vor ihnen zu richten, worauf ein langweiliger Videoclip gezeigt wurde. Gleichzeitig wurden auf einem zweiten Bildschirm rechts daneben aufregende, aufmerksamkeitsregende Clips inklusive Ton abgespielt. Selbstkontrolle wurde dadurch quantifiziert, wie oft und wie lange die Versuchspersonen auf den Ablenkungsbildschirm blickten. Die Resultate zeigten, dass Versuchspersonen in der schnellen Atemgruppe öfter und länger auf den Ablenkungsbildschirm sahen als Personen in der langsamen Atemgruppe, was die Hypothese befürwortet. Zusätzliche Messungen wie Neurotizismus oder der Zeitabstand zur letzten konsumierten Mahlzeit waren partielle Prädiktoren für Selbstkontrollleistung, nicht aber die Einnahme von Psychostimulanzien, das Ausmaß körperlicher Freizeitaktivität oder Überzeugungen von Teilnehmern über Willenskraftdynamiken. Einige HRV-Messungen reflektierten selbstregulatorische Kraft, doch während selbstregulatorischer Anstrengung unterschieden sie sich nicht zwischen den Atemgruppen. Im Anschluss an eine Diskussion dieser Resultate sowie der Einschränkungen dieser Studie und ihrer Relevanz für die Kognitionswissenschaft endet diese Masterarbeit mit einem Vorschlag für künftige Forschung und zieht ein Fazit.

Curriculum Vitae

Education.

2013-2015	MSC MEi:COGSCI
2013	CERTIFICATE IN ADVANCED ENGLISH
2010-2013	BA PHILOSOPHY (BACHELORSTUDIUM PHILOSOPHIE)
2010	MATRICULATION EXAMINATION (BERUFSREIFEPRÜFUNG)
2005-2009	TECHNICAL COLLEGE (FACHSCHULE FÜR DATENVERARBEITUNG)

Scientific Projects.

SS 2015	MASTER PROJECT <i>Effects of Paced Respiration on Attentional Impulse Control</i> supervised by ao. Univ.-Prof. Dipl.-Biol. Dr. Karl Grammer, University of Vienna Presented at MEi:CogSci Conference 2015, Ljubljana, Slovenia
WS 2014/15	MOBILITY SEMESTER PROJECT <i>Using OpenViBE to Test a Brain-Computer Interface Based on Motor Imagery</i> supervised by Prof. Ing. Dr. Igor Farkaš, Comenius University Bratislava, Slovakia
SS 2014	RESEARCH PROJECT <i>Nonverbal Cues During Staredowns Predict Outcome of MMA Fights</i> supervised by Dr. Markus Koppensteiner, University of Vienna Presented at MEi:CogSci Conference 2014, Kraków, Poland
WS 2012/13	BACHELOR THESIS II <i>Psychedelische Wahrnehmung. Eine interdisziplinäre Studie</i> supervised by Mag. Dr. Christoph Weinberger, University of Vienna
SS 2011	BACHELOR THESIS I <i>Wie Spinozisten ihren Hass bekämpfen</i> supervised by Mag. Dr. Bernd Bösel, University of Vienna

Work Experience.

SS 2015	SCIENTIFIC ASSISTANT <i>Project CADDY (Cognitive Autonomous Diving Buddy)</i> Project run by ao. Univ.-Prof. Dipl.-Biol. Dr. Karl Grammer, University of Vienna
WS 2013/14	TUTOR <i>Philosophie des Geistes</i> Lecture held by Dr. Michael Schmitz, MA, University of Vienna
SS 2013	TUTOR <i>Einführung in die theoretische Philosophie</i> Lecture held by Dr. Michael Schmitz, MA, University of Vienna
2009-2010	CIVILIAN SERVICE (ORDENTLICHER ZIVILDIENTST) Lebenshilfe Oberösterreich: Werkstätte Linz-Urfahr, 4040 Linz