PHYSICAL ACTIVITY AND MENTAL HEALTH: MODIFYING EFFECTS OF PERSONALITY

by

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(Under the Direction of Rodney King Dishman)

ABSTRACT

Evidence supports a relationship between physical activity (PA) and affective experience, but studies have been heterogeneous in methods and outcomes. In particular, how individual differences among people (e.g., personality) may modify or otherwise help explain physical activity exposure and its affective outcomes related to mental health has been understudied. This document first summarizes the relevance of personality theory to the relationship between physical activity and positive psychological outcomes. A systematic review and meta-analysis of the literature on PA and personality then corroborates an earlier report of significant relationships between PA level and Extraversion, Neuroticism, and Conscientiousness, and presents new evidence of a significant relationship with Openness. Next, a structural regression model is tested that confirms differences in correlations between personality and PA depending on whether PA was measured with self-reports or accelerometers. Trait level behavioral approach system functioning (BAS) predicted self-reported PA level, whereas trait level behavioral inhibition system functioning (BIS) and Neuroticism predicted objective PA. A suppression effect was observed for the prediction of objective PA by BIS, imposed by Neuroticism. The model was extended to test the role of personality in the relationship between

PA and mental health. Results support moderation by an interaction between Extraversion and Neuroticism. Lastly, a laboratory experiment demonstrated no effect for personality groups based on sensitivity to reward and punishment cues in the effect of acute exercise on the acoustic startle eyeblink response during affective picture viewing, an objective measure of emotional responding. However, these data do suggest a role for cognitive factors, specifically perceptions of control, in modifying subjective ratings of neutral stimuli after exercise. Future research using objective measures of physical activity along with a valid personality tool, and measures of behavioral and/or physiological correlates of personality factors is recommended to more precisely describe the influence of personality on psychological outcomes of exercise. Attempts to identify potential interactions between personality and cognitive factors in effects of exercise on psychological outcomes are also warranted.

INDEX WORDS: Personality; BIS/BAS; physical activity; mental health; affect; acute exercise; perceived control

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# CHAPTER 1

## Introduction and Literature Review

The field of exercise psychology has contributed a large body of knowledge on the relationship between physical activity level and mental health. One particular area of interest is the relationship between physical activity and affect. Affect, or the expression of value given to a feeling state, is clearly linked to overall mental health. In fact, an entire class of disorders has been identified as relating specifically to affect, such as bipolar disorder and depression (American Psychiatric Association, 2000). Physically active individuals report greater positive affect than those who are less active (Poole et al., 2011; Reed & Buck, 2009). The evidence supports a relationship between physical activity and affect, but there remains some inconsistency between studies (e.g. De Moor, Boomsma, Stubbe, Willemsen, & de Geus, 2008; Kawada, Katsumata, Suzuki, & Shimizu, 2007) providing reason for continued research.

Inconsistency may result from a moderator variable. Moderators are variables outside of the associative path between two different variables, such that their relationship differs as a function of level of the moderator variable. Many moderators have been identified in an attempt to more accurately describe the relationship between affect and physical activity, though there remains some ambiguity (Reed & Buck, 2009; Reed & Ones, 2006). After examination of baseline positive activated affect, exercise intensity, exercise duration, exercise dose, post-exercise assessment time, study quality and study source, Reed and Ones (2006) concluded that there is reason to suspect that additional variables possibly related to individual differences moderate exercise effects on positive activated affect. A clear understanding of the moderators of the physical activity/affect relationship is important for proper exercise prescription targeting mental health. Also, such clarification may provide information pertinent to the design of physical activity interventions aimed at maximizing adherence to physical activity, as it has been suggested that affective reactions to exercise may influence future physical activity participation (Kwan & Bryan, 2010; Williams, 2008).

One potential moderator which has received little attention in the literature is personality. Personality accounts for a significant amount of variance in participation in regular physical activity (Rhodes & Smith, 2006), though, examinations of the relationship between personality and physical activity have proceeded with little consideration of the theoretical reason for such a link (Bauman, Sallis, Dzewaltowski, & Owen, 2002). Affective and motivational theories often make connections with personality research because of proposed respective traits. Nonetheless, conceptual models derived from biologically driven theory (e.g. Gray, 1991; Gray & McNaughton, 2000; Zuckerman, 2005) maintain appeal by providing a biological link between behavior and personality.

A description of the influence of personality on the physical activity/affect relationship will likely generate a greater understanding of the inconsistent observations reported in the literature, and provide a means from which to approach subsequent investigations in several directions. Such relationship could play an integral role in understanding observed variation in successful adherence to exercise interventions and exercise effects on psychological outcomes (e.g. anxiety, depression, affect, RPE). The link may also serve as a platform from which to investigate potential pleiotropic genetic mechanisms, as there is evidence that both personality and physical activity are heritable (Jang, Livesley, & Vernon, 1996; Riemann, Angleitner, & Strelau, 1997; Stubbe et al., 2006), change with age, and differ according to gender.

**Personality**

Personality is conceptualized as consisting of stable traits observable within all people, across ages, genders, and cultures. Personality is highly heritable (Jang et al., 1996; Riemann et al., 1997), and has also been observed among several nonhuman animals (Gosling & John, 1999) suggesting a strong biological etiology. Generally, personality dimensions represent enduring and consistent between-subjects differences in predispositions for cognitions, emotions, and behaviors. There is general consensus regarding the hierarchical nature of personality. Contemporary theories agree that there are a few broad first order personality dimensions, hereafter referred to as primary dimensions, each consisting of several lower order traits. Primary dimensions account for a greater amount of variance, and are presumed to be more closely linked to genetics, but lack the specificity provided among lower order traits. Lower order traits are themselves also comprised of several even narrower traits, each level of which becomes continuously more susceptible to exogenous influences. Though not a common practice currently, it should be noted that the measurement of primary personality dimensions is recommended in conjunction with the study of lower order traits to facilitate coordinated science in the study of personality.

Contemporary personality theories developed after a paradigm shift across psychological fields from a static perspective of psychological processes to a dynamic perspective, acknowledging the importance of environmental factors, as well as personal factors, for understanding behavior (see Lewin, 1935). Suddenly, theorists were able to state testable hypotheses about the nature of personality as it relates to environmental factors. How people behave under certain circumstances became a venue through which to describe their individual traits.

Currently, the most popular taxonomy is a five-factor model suggesting that Openness/Intellect, Conscientiousness, Extraversion, Agreeableness, and Neuroticism (OCEAN) are the basic factors of personality (McCrae et al., 2000). Another popular taxonomy is the three-factor model proposed by Eysenck (1970). This model includes the Extraversion and Neuroticism factors, as well as Psychoticism. The two common dimensions to these models, Extraversion and Neuroticism (the "Big 2") have endured among conceptual models supported in the study of personality, and are generally viewed as biologically-based affective components of personality, or as "temperaments" (Watson & Clark, 1992). They are the most consistently represented primary dimensions in the literature. Extraversion reflects the tendency to be sociable, assertive, and energetic, seek excitement and experience positive affect. Neuroticism reflects the tendency to be emotionally unstable, anxious, self-conscious and vulnerable. Both are observed to be highly heritable (Viken, Rose, Kaprio, & Koskenvuo, 1994) and can be distinguished as early as infancy. Though they were initially recognized as personality traits among correlations between Cattell's 16 factors (Cattell, 1947), they were further elaborated as temperaments through the secondary factor analytic work and psychophysiological theorizing of Hans Eysenck, and their characteristics are reflected as central components in most contemporary trait theories. Theorists disagree regarding the number and nature of additional primary dimensions. More work is needed to clarify our understanding of the structure of primary personality.

In addition to commonly recognized factor models, trait psychology has produced several lines of theory concerned with identifying physiological mechanisms that may be responsible for individual differences in traits. One line of work which has generated widespread support is that of Hans Eysenck extended through the work of his student, Jeffrey Gray. Both theorists attempt to bridge the gap between personality psychology and neuroscience, though they used opposing approaches in their attempts; Eysenck took a top-down approach through factor analysis, and Gray took a bottom-up approach through his behavioral neuroscience work with animal models. The work of these two theorists is mostly complementary. The key differences lie in their hypotheses specific to learning and the underlying psychophysiology. It has been suggested that the two theories describe the same fundamental personality dimensions. Eysenck himself acknowledged the applicability and importance of examining the relationship between personality and psychophysiology from both directions, though his work was restricted to the top-down method. It should be noted that neither theory has been observed to hold under all circumstances, though both are strongly supported and represent likely points of departure for current personality theorists. Researchers interested in personality and how it relates to other constructs might benefit from using concurrent measures to capture personality as conceptualized in both theories, rather than curry favor for one perspective or the other. There may be important differences in how affect, cognition and behavior relate to personality measured in alignment with differing theories.

Eysenck began his theoretical work using secondary factor analysis to identify factors of temperament as described by Willhelm Wundt in his theory of two continuums of characteristics accounting for the behavior 'types' described in Galen's doctrine of the four temperaments, or theory of the 'humours' (second century, A.D.). His model was then elaborated based on psychobiological learning theories. Within Eysenckian theory three higher order personality factors, Extraversion, Neuroticism and Psychoticism, were hypothesized through his work with factor analysis and have been widely supported through subsequent factor analyses and correlational studies.

Of Eysenck's three factors, Extraversion has received the most attention. Conceptually, Extraversion and Introversion lie on opposite ends of a bipolar continuum with a normal distribution, and reflect variation in cortical arousal, or arousability. Cortical overarousal and hypersensitivity is presumed among introverts, and hyposensitivity and cortical underarousal among extraverts, to result in the manifestation of their respective behavioral characteristics (Eysenck, 1967). Eysenck further specified that sensitivity of the autonomic nervous systems was responsible for variation in Neuroticism which is also conceptualized as a bipolar normally distributed continuum from Neuroticism to Emotional Stability. Individuals high on Neuroticism are hypothesized to possess an autonomic nervous system that is quick to react to stress and slow to recover, resulting in the behavioral characteristics of Neuroticism. This postulate is less well supported as psychophysiological research has demonstrated inconsistent results. The biological basis of Psychoticism received far less attention from Eysenck than Extraversion and Neuroticism. Despite the widespread use and support for many of Eysenck's hypotheses, the overall simplicity of his psychophysiological model has led to some criticism, and prompted the development of more detailed theories regarding the psychophysiology of personality.

One such theory is Reinforcement Sensitivity Theory (RST), which was proposed by Eysenck's own student, Jeffrey Gray. Gray proposed that three brain systems were of primary importance in describing emotion and behavior and extended this work to suggest that personality arises from the joint functioning of these systems (Gray, 1991). This three system model includes the behavioral inhibition system (BIS), the behavioral approach system (BAS), and the fight/flight/freeze system (FFFS). The BIS is believed to be activated in situations of goal conflict, resulting in inhibition of ongoing behavior, increased arousal, and increased attention (i.e. increased risk assessment, environmental scanning, and internal scanning of the memory)(Gray & McNaughton, 2000). The FFFS is activated to cope with an explicit danger, for which there is an opportunity for escape or avoidance (McNaughton & Corr, 2004). Both of these systems are defensive systems and are thus sensitive to cues of punishment, and nonreward. In addition, the BIS is believed to be responsive to novel stimuli. The differentiating factor between them is "defensive direction." If one must approach an aversive stimulus, the BIS is activated, whereas, if one has no need to approach the aversive stimulus, the FFFS is activated. The action elicited by the FFFS (fight, flight, or freeze) depends on defensive distance, or distance from the explicit danger. Lastly, the BAS is activated by cues of reward or by the opportunity to prevent or stop punishment.

In elaboration of his model, Gray proposed that two personality dimensions, within the same conceptual space as those proposed by Eysenck (Eysenck, 1970; Eysenck & Eysenck, 1985), are of primary importance in understanding individual personality and performance (Gray, 1970, 1981, 1982, 1987, 1991; Gray & McNaughton, 2000). He introduced two orthogonal dimensions of personality to the Eysenckian model at a 30˚ rotation from the orthogonal dimensions Neuroticism and Extraversion. The BIS trait runs from Eysenck's stable extravert (low anxiety) quadrant to his neurotic introvert (high anxiety) quadrant, and the BAS trait runs from the stable introvert (low impulsivity) to the neurotic extrovert (high impulsivity) quadrant. Gray's personality dimensions are theorized to represent stable individual differences in sensitivity of the BIS and BAS, respectively. In other words, BIS/BAS traits reflect relative priming of the BIS and BAS. Accordingly, individuals with greater BAS activation, as indicated by high scores for BAS scales, would be expected to elicit stronger responses in the presence of appetitive stimuli, relative to low scorers for BAS. Likewise, high scorers for BIS would be expected to demonstrate more extreme responses to novelty or cues of danger/punishment, relative to low BIS scorers. The specification of impulsivity as the personality dimension reflecting BAS was completely arbitrary (Gray, Owen, Davis, & Tsaltas, 1983). It has been noted in an integrative review that the BAS has been discussed in terms of Extraversion, impulsivity, novelty seeking and positive affect (Revelle, 1995). Identification of a single BAS trait has proven difficult, and measures developed to assess BAS trait have included several sub-constructs. For example, the constructs "fun seeking", "drive", and "reward responsiveness" have been suggested to be reflective of BAS activation and are included in what is arguably the most commonly used measure of BIS/BAS traits, the BIS/BAS scales (Carver & White, 1994).

An appealing feature in regards to these two theories is their comparability. Gray's work was in part driven by observations and hypotheses made by Eysenck. Indeed, Eysenck's approach to describing individual differences through his factor analytic work was a necessary precursor to Gray's work in the neuropsychology of personality. Before an organized bottom-up examination of biological structures involved in personality was to advance, a top-down description of traits was needed as a conceptual map. It was against Eysenck's conceptual backdrop that Gray placed the dimensions he considered primary to describing personality. So, hypotheses involving behavior can be made under the guise of one system, yet still be directly comparable to the other. It should be emphasized that, though there is expected covariance between measures reflecting different theories, these measures are not capturing the same construct(s). Rather, each observed construct represents unique variance in the true personality construct, which cannot be measured. Any covariance between the observed constructs from opposing theories represents the shared contribution of true personality and relevant environmental exposures within subjects. Of course, covariance between observed constructs within theories would violate the assumption of orthogonal dimensions made by both theorists.

Gray's model holds that individuals who score high for BIS also score high for Neuroticism, whereas those with high BAS scores also score high for Extraversion. Several lines of investigation have supported links between BIS and Neuroticism and between BAS and Extraversion (e.g. Gray, 1987; Hall, Ekkekakis, & Petruzzello, 2005; Heubeck, Wilkinson, & Cologon, 1998; Jackson & Smillie, 2004; Jorm et al., 1999; Keiser & Ross, 2011; Mitchell et al., 2007; Smits & Boeck, 2006), however, the derivation of such constructs is elusive. One investigation used structural equation modeling to examine the efficacy of BIS/BAS profiles as predictors of personality among two large samples of undergraduates in the Netherlands (Smits & Boeck, 2006). They concluded that Neuroticism and Extraversion can be adequately predicted by scores for BIS and BAS. Though such an attempt is clearly needed in the literature, the grounds for making such a bold conclusion are unstable considering the study design used. Though structural equation modeling can be used to examine causal influence, such inferences cannot be made using a cross-sectional design. The coefficients they claim to represent a causal path from BIS/BAS to Extraversion and Neuroticism may very well be indicative of a causal effect in the opposite direction. Due to the stable nature of the variables in question, experimental manipulation to examine causation is difficult. Until such evidence is presented, inference into the causal direction of such relationships is premature, albeit appealing.

Implicit in any theory of personality is the stable nature of the traits. Gray's personality dimensions are theorized to represent stable individual differences in homeostatic activation of the BIS and BAS, respectively. Change over time is expected to be minimal. One study was conducted to determine genetic and environmental impact on the temporal stability of BIS/BAS traits (Takahashi et al., 2007). Results provided evidence of a moderate genetic influence accounting for approximately one-third of the variance. This evidence provides strong support for the validity of BIS and BAS scores reflecting traits.

There is no mention in RST of expected differences according to gender, race, or age in Gray's personality dimensions. However, in regards to self-report measurement, social expectations may provide potential for variance between genders, as men may be less apt to report symptoms of anxiety and women less likely to endorse items expressing aggression. The only set of BIS/BAS trait norms to date was provided according to gender and age group with an Australian community sample (*n*=2725). Jorm and colleagues (1999) found that both BIS and BAS scores are lower in older age groups. Though there were no significant differences between genders for BAS composite scores, females did report higher mean BIS scores than males. This difference was greater in young groups than in older groups. Closer inspection of BAS differences between genders demonstrated that females scored higher for reward responsiveness than males. Among the older age groups, males scored higher than females for the drive subscale.

**Personality and Affect**

In addition to the parallels already discussed between the Eysenckian model and the RST model, the two theories share commonalities in regards to their associations with affect. Affect is commonly viewed as a statement of value provided for a current state of being along two primary dimensions; valence (pleasant vs. unpleasant) and arousal (engaged vs. disengaged; Batson, Shaw, & Oleson, 1992). Though there has been some disagreement regarding the dimensional structure of affect (Russell & Carroll, 1999a, 1999b; Watson & Tellegen, 1999), there is general agreement that these two factors drive individual responses to self-report measures of affect. Additionally, a 'dominance' dimension is commonly included in theories of affect which recognize the connection between affect and behavior in an approach/avoidance context (Bradley & Lang, 1994). It is believed that the BIS and the BAS produce affective qualities that are relevant to avoidance and approach, as well as aversive and appetitive cues, respectively (Gray, 1982; Gray & McNaughton, 2000).

Approach and avoidance behaviors are thought to induce positive and negative feelings as a function of progress towards a goal (Carver, 2001; Carver & Scheier, 1990). Affect, elicited in the presence of appetitive or aversive cues, drives behavior that results in progress towards a goal, which then results in affect relative to such progress. The specific emotions or feelings reported will depend on the nature of the goal. For example, poor progress in an attempt to reach an approach goal may result in frustration whereas similar progress in the context of an avoidance goal may induce fear. According to this line of thought, affect is a result of, and contributor to, a self-regulatory feedback loop that compares desired progress to actual progress and functions to inform the organism of the current progress and aid in the selection of subsequent behavior.

Although momentary affect is transient, trait measures of affect reflect stable individual differences in predispositions to experience aversive emotional states, such as anxiety, fear, guilt and sadness, and positive emotional states, such as eagerness, cheerfulness, confidence and enthusiasm (Watson, Wiese, Vaidya, & Tellegen, 1999). Moreover, these affective dispositions are found to be strongly and systematically related to more general personality dimensions (Watson & Clark, 1992). Strong associations between Neuroticism and BIS, as well as Extraversion and BAS have been observed, paralleling the associations between Extraversion and positive affect, and Neuroticism and negative affect. Additionally, high BAS scorers tend to report more positive affect and positive experiences than low BAS scorers, whereas high BIS scorers tend to report more negative affect and negative experiences than low BIS scorers (Gable, Reis, & Elliot, 2000). These observations provide additional support for the view that affect is in part a result of the functioning of the BIS and the BAS (Gray, 1982; Gray & McNaughton, 2000).

**Physical Activity and Affect**

It is commonly agreed upon that individuals report improved mood following a bout of physical activity or exercise (Berger & Motl, 2000; Byrne & Byrne, 1993; Giacobbi, Hausenblas, & Frye, 2005; Morgan, 1985; Moses, Steptoe, Mathews, & Edwards, 1989; Roth, 1989; Steinberg et al., 1998; Yeung, 1996). Physical activity is defined as bodily movement caused by skeletal muscles that results in increased energy expenditure (Caspersen, Powell, & Christenson, 1985). This includes purposeful exercise, as well as incidental movement. In an examination of varying strategies for self-regulating mood, exercise was reported to be the most efficacious method of mood regulation, followed closely by listening to music, social contact, doing chores, resting, cognition control, and several others, though it wasn't reported to be the most frequently used tactic (Thayer, Newman, & McClain, 1994). Effects have been demonstrated across a spectrum of acute exercise of varying modes, intensities, and durations (Dunn, Trivedi, & O'Neal, 2001).

The available evidence on the relationship between physical activity and affect has largely focused on positive activated affect. One meta-analysis of the effects of regular aerobic exercise on positive activated affect concluded that relative to control groups, aerobic exercise programs produce moderate improvements ($d_{corr}$ = .57, $SD_{corr}$ = .48) in self-reported positive activated affect (Reed & Buck, 2009). It should be noted that the majority of the scales used in the studies examined measured positive activated affect in the "right now" (62.25%) as opposed to the “one week” (16.85%) time set. The remainder of the studies did not specify the time frame used (20.90%). Results were reported for the entire sample only. It is therefore unclear whether an examination of acute effects and chronic effects separately may result in differing effect sizes.

It is important to describe affective responses to exercise, as they likely have a hand in continued participation in physical activity behavior (Kwan & Bryan, 2010; Williams et al., 2008) and resulting mental health benefits. A positive relationship between physical activity and several aspects of mental health is widely documented (Physical Activity Guidelines Advisory Committee, 2008). The accumulated evidence particularly supports that physical activity is associated with reduced symptoms of anxiety or depression in prospective cohort studies (e.g. Beard, Heathcote, Brooks, Earnest, & Kelly, 2007; Brown, Ford, Burton, Marshall, & Dobson, 2005; R.K. Dishman et al., 2012; Jonsdottir, Rodjer, Hadzibarjramovic, Borjesson, & Ahlborg, 2010; Sanchez-Villegas et al., 2008; Strawbridge, Deleger, Roberts, & Kaplan, 2002; Wise, Adams-Campbell, Palmer, & Rosenberg, 2006) and randomized trials in patients (Asmundson et al., 2013; Herring, 2010; Herring, Jacob, Suveg, Dishman, & O'Connor, 2012; Ströhle, 2009) or healthy adults (Conn, 2010; Long & Van Stavel, 1995). Similarly, prospective population surveys (Heesch, Burton, & Brown, 2011; Tessier et al., 2007; Wolin, Glynn, Colditz, Lee, & Kawachi, 2007) and a randomized trial (C. K. Martin, Church, Thompson, Earnest, & Blair, 2009) of women reported that physical activity is positively associated with better mental health when it is defined more generally by a combination of symptoms of anxiety and depression. However, other evidence has suggested that the association of physical activity with anxiety or depression symptoms is not direct and might be confounded with, or otherwise explained by, personality (De Moor, Beem, Stubbe, Boomsma, & De Geus, 2006).

Several potential confounders of the association between exercise and affect have been examined in attempts to account for observed variance in effects. In their meta-analysis of the effects of regular aerobic exercise and positive activated affect, Reed and Buck (2009) conducted separate analyses for potential moderators, including baseline positive activated affect, exercise frequency, exercise intensity, exercise time, program duration, exercise dose, and study quality and source. Moderator analyses suggest that larger effects can be expected for those with lower baseline positive activated affect, individuals who exercise >3 days/week, those participating in low or high intensity exercise, and individuals who exercise for 30-35 minutes per bout. Results also supported a moderator effect of threats controlled, indicating a greater effect in studies having higher internal consistency. Reed and Buck acknowledge that several of the variables examined have the potential to be dependent on unexamined moderators. Personality was not included in the moderator analyses. It may be the case that personality plays a role in the influence of several of the examined moderators. Reed and Ones (2006) conducted a meta-analysis to summarize the effect of several potential moderators of the effects of acute exercise on positive activated affect, but did not include personality factors. Due to the theoretical ties between the origin of affect and personality (Gray, 1982; Gray & McNaughton, 2000), there is reason to examine the moderating role of personality in affective responses to acute exercise.

**Personality and Physical Activity**

Surprisingly, there has been little investigation into the association between BIS/BAS and physical activity level. Cross-sectional evidence was provided by Voigt and colleagues (2009) in their examination of the associations between BIS/BAS and risky health behaviors. A sample of 1014 undergraduates, from four universities in the United States, completed self-report measures for BIS/BAS and frequency of engagement in various health behaviors. The physical activity composite score was represented by the amount of weekly physical activity reported, as well as the amount of time spent watching TV or playing video/computer games, derived from three items (e.g. "During the past 7 days, on how many days were you physically active for a total of at least 60 minutes per day?"). Individuals with higher BIS scores were found to be more likely to report inactivity. The drive subscale of the BAS was found to be inversely related to inactivity ($r$ = -.16), indicating that individuals with high scores on the drive subscale are more likely to report higher levels of activity. There is also evidence that BIS/BAS traits influence subjective rating of exertion and affect during exercise (Hall et al., 2005; Schneider & Graham, 2009), though such reports are scarce.

Higher levels of physical activity are associated with higher levels of Extraversion and Emotional Stability (Courneya, Bobick, & Schinke, 1999; Davis, Fox, Brewer, & Ratusny, 1995; De Moor et al., 2006; Rhodes & Smith, 2006) and high-level exercisers have been observed to be more extraverted than low-level exercisers and non-athletes (Davis & Fox, 1993). Moreover, it has been observed that those who are emotionally stable and extraverted have significantly higher levels of both physical and psychological motivation toward exercise participation, and tend to engage in more exercise (Chu-Hsin, Li-Yueh, & Man-Ling, 2007). One meta-analysis confirmed that physical activity is correlated with Extraversion ($r$ = 0.23), Neuroticism ($r$ = -0.11) and Conscientiousness ($r$ = 0.20) (Rhodes & Smith, 2006). Lochbaum et al. (2010) conducted a follow up study to examine whether gender was a significant moderator of the personality/physical activity relationship and concluded that gender does not significantly moderate the effect of personality on physical activity.

Lochbaum and colleagues (Lochbaum & Lutz, 2005; Lochbaum et al., 2010) discuss the potential for designing exercise interventions according to personality profiles to ensure maximum compliance and adherence. Extending that line of thought, we might consider that exercise interventions designed to target specific results (i.e. adherence, weight loss, etc.) may benefit from personality specific exercise prescription. In specific regard to affect, and the affective disorders, the most advantageous exercise prescription likely varies according to personality profiles. Research is needed to more accurately describe the differentiating effect of major personality dimensions and individual differences in BIS/BAS traits on the affective response to physical activity and exercise.

**Personality, Physical Activity, and Affect**

Strong support for the dynamic relationship between personality, physical activity and affect is found in a large population based investigation of the relationship between exercise with anxiety, depression, and personality as a function of age and gender (De Moor et al., 2006). A total of 19,288 participants from The Netherlands Twin Registry provided self-report data every 2 years between 1991 and 2002, resulting in a total of 43,888 observations included in the study. Individuals reporting at least 60 minutes of moderate intensity exercise (4 METS) were considered exercisers. As age increased, a steady decline in physical activity level was observed for both genders. Females were more active than males at older ages, whereas males were more active than females at younger ages. Exercisers were reportedly more extraverted (0.32 SD), and less neurotic (-0.14), depressed (-0.29 SD), and anxious (-0.18 SD), than non-exercisers. The authors noted that, though modest, these differences are very consistent across age and gender.

Though there have been no studies examining affect and physical activity level relative to BIS/BAS traits, support for the relationship between BIS/BAS, physical activity, and affect is drawn from observations of differing subjective responses to acute exercise according to

BIS/BAS profiles (Hall et al., 2005; Schneider & Graham, 2009). BIS and BAS traits have demonstrated relationships with self-reported ratings of perceived exertion (RPE; Hall et al., 2005), and affective response during exercise (Schneider & Graham, 2009). Specifically, BIS has been shown to be positively related to RPE during low, moderate and high exercise intensities, and BAS negatively correlated with RPE at low intensity only. Therefore, individuals with high scores for BIS tend to report greater perceived exertion during exercise, regardless to intensity (Hall et al., 2005). These observations were not controlled for recent physical activity or fitness and may not be consistent across ages, however (Schneider & Graham, 2009). Additionally, associations between BIS/BAS traits and subjectively reported affect during exercise at varying intensities have been observed among adolescents (Schneider & Graham, 2009) though investigations of other age groups have not yet been published.

**Summary**

Testing moderators of the physical activity/affect relationship is important for proper exercise prescription targeting mental health and/or physical activity adherence. The available evidence supports a test of the hypothesis that personality accounts for significant variation in the effect of physical activity on affect. The chapters that follow provide a quantitative synthesis of the literature on personality and physical activity, a structural regression model of the interrelationships between personality, physical activity and mental health, and a report on a laboratory experiment testing the impact of individual differences in sensitivity to cues of reward or punishment on changes in emotional responding to aversive and appetitive stimuli after exercise with and without perceptions of control, or quiet rest.

CHAPTER 2

# Personality and Physical Activity: A Systematic Review and Meta-Analysis

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**Abstract**

Whether personality determines physical activity or its outcomes is relevant for theory and public health but has been understudied. We estimated the population correlation between Big-Five personality factors and physical activity and examined whether it varied according to sample characteristics and study features. Database searches were conducted according to PRISMA guidelines, for articles published in the English language prior to November 1st, 2013. Sixty-four studies including a total of 88400 participants yielded effects (k) for Extraversion (88), Neuroticism (82), Conscientiousness (69), Openness (51) and Agreeableness (52). Significant mean *r* was found for Extraversion ($r$ = .1076), Neuroticism ($r$ = -.0710), Conscientiousness ($r$ = .1037) and Openness ($r$ = .0344), but not Agreeableness ($r$ = .0020). Effects were moderately heterogeneous ($I^2$ range = 44% to 65%) and varied by sample characteristics (e.g., age, gender, or clinical status) and/or study features (e.g., measure quality or item format). This analysis expands results of previous reviews and provides new support for a relationship between physical activity and Openness. Future studies should use better measures of physical activity and prospective designs, adjust for statistical artifacts, and consider advances in the conceptualization of personality.

**Introduction**

Physical activity among adults and youths in the US is below levels recommended for health promotion (Centers for Disease Control and Prevention, 2007; Physical Activity Guidelines Advisory Committee, 2008; US Department of Health and Human Services, 2010) and is a target of public health interventions, which often have modest success (Heath et al., 2012; Kriemler et al., 2011; Metcalf, Henley, & Wilkig, 2012). Factors that may modify the success of physical activity interventions, or their varying health outcomes (Bouchard, Blair, Church, & et al., 2012) have received little study. However, theory (Eysenck & Eysenck, 1985; Gray, 1991; McCrae & Costa, 1999) and some evidence from observational studies (Rhodes & Smith, 2006) suggests that personality explains some of the natural variation in physical activity. Personality may also help explain or modify commonly reported (Herring, Jacob, et al., 2012; Herring, O'Connor, & Dishman, 2010; Herring, Puetz, O'Connor, & Dishman, 2012; Physical Activity Guidelines Advisory Committee, 2008) associations between physical activity and several aspects of mental health (De Moor et al. 2006). Furthermore, such associations could serve as a platform from which to investigate  genetic factors common to personality and physical activity (Bouchard & McGue, 2003; Bray, Hagberg, Perusse, & et al., 2009; Dishman, 2008; Jang, Livesley, & Vernon, 1996; Riemann, Angleitner, & Strelau, 1997; Stubbe et al., 2006).

Personality consists of stable traits, observable within people across ages, genders, and cultures. Generally, traits represent enduring and consistent between-person differences in predispositions for cognitions, emotions, and behaviors.  The study of personality has overcome several obstacles in both the conceptualization of testable and observationally supported constructs, as well as their measurement (Eysenck, 1991; John & Srivastava, 1999).  A wealth of evidence supports the existence of five primary factors of personality (Digman, 1989; Goldberg, 1993; McCrae & Costa, 1987; O'Connor, 2002), though reliance on self-report measures and factor analysis has led to some criticism of the five factor model by those in favor of theories postulating fewer primary dimensions and offering testable hypotheses about underlying physiology (e.g. Eysenck & Eysenck, 1985; Gray, 1991; Zuckerman, 2005), or by those claiming that five factors are not enough to account for important individual differences in behavior (Paunonen & Jackson, 2000). Nevertheless, most of the literature involving personality and physical activity has used either Eysenck's three factor model (Eysenck & Eysenck, 1985) or the Five Factor Model of personality (McCrae & Costa, 1999).

Physical activity is defined as bodily movement caused by skeletal muscles that results in increased energy expenditure (Caspersen et al., 1985), including purposeful exercise. Physical activity is complex. It encompasses several dimensions (frequency, intensity, timing, and type), which present a challenge for physical activity measurement (Tudor-Locke & Myers, 2001). Much of the evidence on physical activity and personality is based on data collected with physical activity measures of varying quality, including the use of single-item or author-adapted self-reports and dichotomies of active or inactive participants.

A prior meta-analysis of 33 studies (Rhodes & Smith, 2006) reported heterogeneous correlations between physical activity and Extraversion ($r$ = 0.23), Conscientiousness ($r$ = 0.20) and Neuroticism ($r$ = -0.11). However heterogeneity statistics were not provided, nor were there enough retrieved effects to test for potential moderators. Analyses for moderation of significant associations between physical activity and personality should include tests of sample characteristics relevant to either construct as well as qualities of construct measurement that differ between studies. Furthermore, common traits, such as Extraversion and Neuroticism, measured in alignment with differing theories may reflect similar yet inequivalent psychological constructs, potentially biasing observed relationships; this possibility should be considered when aggregating effects. The aim of the systematic review and meta-analysis reported here is to estimate the population correlation between personality and physical activity and examine whether it varies according to selected sample characteristics and study features.

**Methods**

**Data searches.** In accordance with PRISMA guidelines (Moher, Liberati, Tetzlaff, & Altman, 2009), we conducted an extensive database search of articles published prior to November 1st, 2013. Searches of PubMed, Web of Science, Medline, PsycInfo, GoogleScholar, and SportDiscus using the search terms *exercise* or *physical activity* plus one of the following: *personality, big five, five factor model, Extraversion, extravert, Neuroticism, neurotic, emotional stability, openness, agreeableness, conscientiousness, psychoticism, trait anxiety, trait impulsivity, sensitivity to punishment, sensitivity to reward, positive affectivity, negative affectivity, positive emotionality, negative emotionality, BIS, BAS, behavioral inhibition, behavioral activation, or behavioral approach.* Searches were restricted to titles and abstracts containing the specified key words, and written in English. Manual searches of the references listed in retained articles were also conducted.

**Selection of studies.** Inclusion extended to published articles that measured physical activity behavior and one or more major personality trait, and required the use of a valid personality instrument. Measures of fitness were excluded as they are correlated with, though not measures of, physical activity behavior (Caspersen et al., 1985). Likewise, we excluded studies comparing athletes and non-athletes as such a dichotomization is reflective of participation in organized, competitive activities, rather than physical activity level. To control for attenuation of effects resulting from extreme range restriction (Hunter, Schmidt, & Le, 2006), we excluded studies that used physical activity as an inclusion or exclusion factor (i.e. only recruiting athletes or sedentary people). Variables of interest were measured as continuous or discrete, comparing groups scoring high or low on the respective variable. Attempts were made to contact the corresponding author for studies that reported measuring physical activity and personality but did not report enough information to calculate effect sizes.

A preliminary examination of the search results revealed that only the traits Extraversion, Neuroticism, Conscientiousness, Openness, and Agreeableness yielded 10 or more effects. Inclusion was therefore restricted to those studies reporting effects compatible with the Five Factor Model, commonly referred to as the "Big Five" (John & Srivastava, 1999). This included effects for which Extraversion and Neuroticism were measured as conceptualized in the five factor model, as well as by Eysenck (1970) and Cattell (1947). A preliminary moderator analysis found no difference in effect according to personality model used for the measurement of Extraversion and Neuroticism. Therefore, effects from differing personality models were retained. Based on theoretical expectations (Eysenck, 1967; Eysenck, Nias, & Cox, 1982; John & Srivastava, 1999; McCrae & Costa, 1999) and previous reports (Rhodes & Dickau, 2013; Rhodes & Smith, 2006), we expected to find positive associations between physical activity level and Extraversion and Conscientiousness, and a negative association with Neuroticism.

**Effect size calculation.** Included effects were recorded independently by the first author, and represent bivariate relationships between physical activity level and the respective trait. Among cases with more than two physical activity categories, groups were collapsed to form meaningful dichotomies for effect size calculation (e.g. high or low active; active or inactive). Studies that measured physical activity using stages of change from the Transtheoretical Model were included when effects could be derived for mean differences between those in the 'action' or 'maintenance' stages and those in the 'preparation' stage or earlier, resulting in an "active or inactive" dichotomy. Sample size was used to cross-reference and confirm that data provided by authors responding to a request for more information matched the sample reported on in the respective publication.

Point biserial *r* was derived from effect size *d* for effects reported as means and standard deviations or independent samples *t* tests. Adjustments for false dichotomization and reports of point biserial or phi coefficients were made according to Hunter and Schmidt (1990), to derive estimates of *r* and its sampling error adjusted for false dichotomization of the independent and dependent variables. Insufficient reporting of reliability statistics prohibited the correction for range restriction (Hunter et al., 2006), as well as measurement error (Hunter & Schmidt, 2004). In accordance with standards for meta-analysis of *r*, all correlations were standardized using Fisher's *z* prior to aggregation and regression moderator analysis, and then were back-transformed to reflect the population correlation (Rosenthal, 1991).

**Selection and coding of moderators.** Sufficient reporting allowed examination of several potential effect modifiers. See Table 2.1. At least 5 effects per moderator level were required for inclusion in the moderator analyses. When necessary, groups were collapsed to accommodate the group size requirement so as to maximize the number of included effects, while preserving a meaningful comparison. In the most extreme case, the analysis for age as a moderator of the association between physical activity and both Agreeableness and Openness was collapsed to create a dichotomy: those less than, or greater than 35 years of age.

***Sample characteristics*.** Sufficiently reported sample characteristics relevant to the study of physical activity and/or personality included (1) age, (2) gender, (3) clinical status (clinical vs.

nonclinical), and (4) geographic region (North America vs. Europe). Age is an obvious candidate for effect moderation, since both physical activity (Caspersen, Pereira, & Curran, 2000) and personality (Roberts, Walton, & Viechtbauer, 2006) are observed to change with age. Though there is evidence to suggest that gender does not moderate the relationship between personality and physical activity (Lochbaum et al., 2010), the sample used in that investigation was age range restricted. It is plausible that an examination of gender as it interacts with other potential moderators will reveal a more complex relationship between gender, physical activity, and primary personality. Moderation by clinical status may be of special interest to clinicians utilizing physical activity as a treatment. For example, if clinical status interacts with one or more personality trait to influence physical activity level, clinicians may have the advantage of identifying those at a heightened risk for poor treatment adherence. Lastly, an examination of moderation by country or culture is of specific relevance to postulates of personality theory, and is also supported by observed geographic variation in physical activity level (Stubbe et al., 2006). Attempts to collapse effects into meaningful comparisons resulted in a dichotomy of effects derived in North America and Europe.

***Study features.*** We also examined moderation by several relevant study features including study design, physical activity measurement quality and definition, personality scale item format, and presence or absence of experimental demand. The relevance of study design is highlighted by reported moderation in the previous meta-analysis (Rhodes & Smith, 2006), in which effects derived from prospective designs were larger than those from cross-sectional designs. To compensate for our efforts to be as inclusive as possible, and to assess the risk of bias resulting from the use of poor quality physical activity measures, we examined moderation by physical activity measurement quality. The number of retrieved effects allowed for a dichotomous comparison: (1) self-report and objective measures with evidence of validity, hereafter referred to as ‘valid’ measures, and (2) self-report measures with uncertain validity, referred to here as ‘unvalidated’ measures. Effects were also coded for the operational definition of physical activity in each study. Levels included (1) volume, representative of overall energy expenditure, commonly reported as METs/time, (2) general quantity, a measure of frequency of physical activity meeting a minimum time requirement without reference to intensity, (3) quantity of moderate to vigorous and (4) quantity of mild to moderate physical activity, reflecting frequency of continuous physical activity at a specified intensity meeting a minimum duration (e.g. bouts per week of moderate to vigorous activity lasting at least 20 minutes), (5) frequency, and (6) active/inactive dichotomy. Effects were coded to reflect personality scale item type as personality measurement has evolved from (1) adjective checklists to (2) surveys using full statement or question item format. Finally, effects were coded to indicate the imposition of experimental demand, here defined as the measurement of intention to participate in physical activity prior to the period during which physical activity was measured.

**Statistical analysis.** A random-effects model was used to aggregate the mean correlation between physical activity and each of the Big Five personality traits (Hedges & Olkin, 1985; Lipsey & Wilson, 2001) using SPSS Macro MeanES (IBM, 2010; Wilson, 2006). Heterogeneity of effects was tested using Q and $I^2$ (Higgins, Simon, Deeks, & Altman, 2003). A significant Q reflects heterogeneity between effects, whereas $I^2$ indicates the percentage of between effect variance that is not sampling error. Conventionally, $I^2$ values approximating 25%, 50%, or 75% and greater indicate low, moderate, or high heterogeneity. Effects were nested within studies, which might systematically differ from each other. Therefore, to adjust for between-study variance and correlated effects within studies, a multi-level mixed linear regression model with robust maximum likelihood estimation was also applied according to standard procedures (Hox, 2010; Cheung, 2008) in Mplus 7.11 (Muthén & Muthén, 1998-2013). Parameters and their errors were estimated with clustering on study using the Huber-White sandwich estimator to calculate standard errors that are robust to hetero-scedasticity and correlated effects (White, 1998; Froot, 1989; Williams, 2000). The number of unpublished or un-retrieved effects averaging zero from samples of mean size that would diminish the significance of observed effects to $p > .05$ was estimated as fail-safe N+ (Rosenberg, 2005). Funnel plots were graphed and evaluated (Egger, Smith, Schneider, & Minder, 1997) to estimate possible publication bias (Sterne et al., 2011).

All moderator analyses were pre-specified and were conducted using random effects maximum likelihood estimation. Mean effects and 95% CI were computed using SPSS Macro MeanES (IBM, 2010; D. Wilson, 2006) and then compared according to planned contrasts (Rosenthal, 1991) using regression analysis by SPSS Macro MetaReg (IBM, 2010; D. Wilson, 2006). Multiple regression models were used to test the independence of significant univariate effects. In subsequent multi-level models, the effect of each independent moderator was first tested separately by comparing each conditional model (which included the intercept and the moderator) with the unconditional intercept-only model using a likelihood ratio test and the adjusted Bayesian Information Criterion (BIC) (Muthén & Muthén, 1998-2013). Limited cell numbers prohibited the examination of 3-way interactions. Significant 2-way interactions were decomposed using simple contrasts (Rosenthal, 1991). Because moderator levels for features of the physical activity construct were not ordinal, a random effects analog to a one way ANOVA (SPSS Macro MetaF; SPSS 21.0, IBM, 2012; Wilson, 2006) was used to examine possible moderation by features of the physical activity construct followed by contrasts with Bonferroni-adjustment to protect alpha at $p < .05$.

**Results**

Figure 2.1 describes the screening process for included studies. A total 7370 records were screened, 521 were assessed for eligibility, and 64 studies including a total of 88,400 participants were included, 49 of which reported enough information for effect size calculation and 15 for which values were obtained from the corresponding author. Mean age of the samples ranged from 14.8 to 92.9 years old. Among the studies using validated physical activity tools, 10 used the Godin LTEQ (Shephard, 1997), 6 used self-report items borrowed from epidemiological research, 2 used frequency of facility use, 2 used program adherence, and each of the following were used once: accelerometers, the Dutch IPAQ (Craig, Marshall, Sjöström, et al., 2003), a physical activity diary and the GPAQ (Armstrong & Bull, 2006). Among the studies using an unvalidated physical activity measure, 21 studies reported using a nonspecific or author-adapted self-report, 12 used a single self-report item, 3 used a nonspecific or unvalidated interview, 2 measured physical activity using stages of the Transtheoretical Model (Prochaska & Velicer, 1997), and each of the following were used once: the Personal Lifestyle Questionnaire (Muhlenkamp & Brown, 1983), Physical Activity Scale 2 (Andersen, Groenvold, Jørgensen, & Aadahl, 2010), and Kirkcaldy's Recreational Interest Inventory (Kirkcaldy & Furnam, 1991). Descriptive details for each included study are listed in Table 2.1. Forest plots for each trait (Figures 2.2-2.6) display weighted effect sizes and their variance according to study for each included effect.

**Mean effects.** The total number of effects, the mean effect sizes (95% CI), and the heterogeneity statistics Q and $I^2$ for the association of each of the Big Five traits with physical activity, as well as values for each moderator level and the contrast weights used in regression moderator analyses, are displayed in Tables 2.2-2.6. The number of studies and derived effects, respectively, for each personality trait were: 56 and 88 for Extraversion, 54 and 82 for Neuroticism, 38 and 69 for Conscientiousness, 30 and 51 for Openness and 29 and52 for Agreeableness. Studies contributing more than one effect for a trait reported an average of 3 effects per trait. Mean effect size *r* for physical activity and Extraversion ($r$ = .108, 95% CI =.0914, .1238), Neuroticism ($r$ = -.071, 95% CI = -.0867, -.0554), Conscientiousness ($r$ = .104, 95% CI = .0837, .124), and Openness ($r$ = .034, 95% CI = .0128, .0560) were all statistically significant ($p$ < .01). The mean effect size *r* for Agreeableness and physical activity was not statistically significant ($r$ = .002, 95% CI = -.0169, .0208, $p$ = .8392). In multi-level models, mean effect r was: Extraversion ($r$ = .112, 95% CI =.0844, .1385), Neuroticism ($r$ = -.072, 95% CI = -.0934, -.0504), Conscientiousness ($r$ = .107, 95% CI = .0755, .1375), Openness ($r$ = .037, 95% CI = .0017, .0722), and Agreeableness ($r$ = .001, 95% CI = -.0245, .0265), with significant variance for all effects except Agreeableness ($z$ = 0.87, $p$ = .386). Mean effects for all of the Big Five were moderately heterogeneous ($I^2$ range = 44% to 65%), which is apparent in the funnel plots generated for each of the dimensions (Figures 2.7-2.11). Egger's test for bias was significant for all personality dimensions ($t$-values 3.0 to 7.8, $p \leq$ .003) except Agreeableness ($t$-value =- 0.124, $p$=.902). However, the mean effects for these four traits remained significant ($p \leq$ .0017) and heterogeneous (Q's 100.45 to 236.15, and $I^2$ from 51.31 to 64.01) in sensitivity analyses that excluded effects derived from sample sizes larger than the mean sample size plus 3 standard deviations (two total effects removed from Extraversion, and one each from Neuroticism, Conscientiousness, and Openness). Funnel plots were generally symmetrical though several outlying effects were observed for each trait. Initially, failsafe N's were illogically large (e.g. >20,000 for Extraversion). However, after removal of four effects from the largest outlying sample sizes (> 3 SD), fail-safe N was 9694 for Extraversion, 4552 for Neuroticism, 3161 for Conscientiousness, and 164 for Openness.

**Moderator analyses: Extraversion.** Moderator analyses revealed that geographic region, experimental demand, and physical activity definition were independent moderators of the relationship between physical activity and Extraversion. The correlation was larger in studies conducted in North America ($\beta$ = .370, $z$ = 4.38, $p$ < .0001) and those including a measure of intention ($\beta$ = .372, $z$ = 4.41, $p$ < .0001). The correlation was smaller when physical activity was defined as quantity of mild to moderate physical activity compared to all other physical activity construct features ($\beta$ = - .329, $z$ = -3.89, $p$ = .0001). In the multi-level model, only physical activity definition remained significant ($\beta$ = -.079, SE = .019, $z$ = -4.25, p < .0001). Model fit ($\chi$2 (5) = 290.2, BIC = 296) was improved compared to the intercept-only model ($\Delta$ $\chi$2 (3) = 501.2, $p$ < .0001, BIC 296 vs. 340).

Significant 2-way interactions were found for gender and geographic region ($z$ = 2.24, $p$ = .0252) and gender and experimental demand ($z$ = 2.79, $p$ =. 0052). European females exhibited a smaller effect than all other groups combined ($z$ = 2.76, $p$ = .0058). This difference remained significant when comparing European females to just North American females ($z$ = 2.54, $p$ = .0112). Females under experimental demand exhibited stronger effects than all subjects without experimental demand ($z$ = 4.45, $p$ < .0001) as well as all other groups combined ($z$ = 3.94, $p$ = .0001). Studies of females under experimental demand reported smaller effects than all studies employing such measure ($z$ = 3.00, $p$ = .0027). Modeled together, the gender-by-experimental demand remained significant ($z$ = 2.36, $p$ = .0184) but the gender-by-region was not ($z$ = 1.78, $p$ = .075).

In the multi-level model, the gender-by-experimental demand remained significant ($z = 2.48$, $p = .013$). Model fit ($\chi^2$ (3) = 294.0, BIC = 300) was improved compared to the intercept-only model ($\Delta\chi^2$ (2) = 446.8, $p < .0001$, BIC was 300 vs. 340). The residual variance was .005 (SE= .003, $z = 1.72$, $p = .085$), indicating that 29% of the variance between effects was explained by the conditional model.

**Moderator analyses: Neuroticism.** Geographic region was the only significant univariate moderator of the relationship between physical activity and Neuroticism. Effects were larger for studies conducted in North America than those conducted in Europe ($\beta = -.2888$, SE = .0092, $z = -2.6361$, $p = .0084$). In the multi-level model, the effect of geographic region was no longer significant ($z = 0.083$, $p = .406$). Significant 2 way interactions were observed for gender and geographic region z = 2.81, ($p = .0049$), as well as gender and physical activity measurement quality ($z = 2.20$, $p = .0280$). Contrasts showed that European females exhibit a stronger relationship between Neuroticism and physical activity than all other groups combined ($z = 3.18$, $p = .0014$). This difference remained significant when comparing North American females only to European North American females ($z = 2.80$, $p = .0052$). Also, females measured with validated physical activity instruments had stronger effects than all other groups combined ($z = 2.02$, $p = .0434$). This difference remained significant when comparing females measured with validated physical activity instruments to just females responding to unvalidated physical activity measures ($z = 2.58$, $p = .0099$). Modeled together, the gender-by-region effect was significant ($z = 2.44$, $p = .0146$) but the gender-by-measurement quality effect was no longer significant ($z = 1.63$, $p = .1025$). In the multi-level model, neither the gender-by-region effect ($p = .918$) nor the gender-by-measurement quality effect ($p = .395$) were significant.

**Moderator analyses: Conscientiousness.** Univariate moderation of the relationship between Conscientiousness and physical activity was observed by study design, physical activity definition, personality scale item format, and experimental demand. Results favored prospective studies ($\beta$ = -.3055, SE = .0116, $z$ = -2.6495, $p$ = .0081), studies that used personality items written as statements or questions ($\beta$ = .3352, SE = .0222, $z$ = 2.9799, $p$ = .0029), and studies imposing experimental demand ($\beta$ = -.5854, SE = .0108, $z$ = -5.9323, $p$ = .0000). Effects from studies measuring frequency of physical activity were consistently larger than effects from other definitions of physical activity ($z$ = 3.56, $p$ = .0004). Modeled together, personality scale item format (z = 3.63, p < .0003) and experimental demand ($z$ = 5.00, $p$ < .0001) remained significant, but study design ($z$ = 0.089, $p$ = .929) and physical activity definition ($z$ = 0.520, $p$ = .603) were not independently related to effect size. In the multi-level model, the effect for experimental demand remained significant ($z$ = 2.23, $p$ = .026) and the effect for personality measure item format was nearly significant ($z$ = 1.82, $p$ = .069).

Two significant 2 way interactions were observed: (1) physical activity measurement quality and experimental demand ($p$ = .0035), and (2) physical activity measurement quality and personality item format ($p$ = .0009). Modeled together, the interaction of physical activity measure quality with experimental demand ($z$ = 2.29, $p$ = .0222) and with personality item format ($z$ = 2.08, $p$ = .0379) remained independently related to effect size. Both groups of effects from studies imposing experimental demand were stronger than all other groups combined regardless of physical activity measurement quality ($p$ < .05). Effects from studies using a valid physical activity tool with experimental demand exhibit stronger effects than all other groups combined ($z$ =2.35, $p$ = .0186), and effects from studies using an unvalidated physical activity measure with experimental demand have stronger effects than those without ($z$ = 5.30, $p$ <

.0001), as well as all other groups combined ($z$ = 5.10, $p$ < .0001). Studies using an unvalidated physical activity tool without experimental demand have weaker effects than all other groups combined ($z$ = 3.56, $p$ = .0004). Effects derived from unvalidated physical activity measures in conjunction with statement or question personality items had stronger effects than those with adjective personality items ($z$ = 3.95, $p$ = .0001) or any study including adjective personality items ($z$ = 3.07, $p$ = .0021). Unvalidated physical activity measures used with personality items in adjective format yielded weaker effects than those from studies measuring personality in statement or question format ($z$ = 3.98, $p$ = .0001) and compared to all other groups combined ($z$ = 4.60, $p$ < .0001).

In the multi-level model, the interaction of physical activity measure quality with experimental demand was no longer significant ($z$ = 0.02, $p$ = .985), but the interaction of physical activity with personality item format remained significant ($z$ = 2.43, $p$ = .015). Model fit ($\chi^2$ (7) = 196.4, BIC = 204) was improved compared to the intercept-only model ($\Delta\ \chi^2$ (5) = 24.8, $p$ < .0001, BIC 204 vs. 229). The residual variance was .003 (SE= .001, $z$ = 1.88, $p$ = .06), indicating that 40% of the variance between effects was explained by the conditional model.

**Moderator analyses: Openness.** The relationship between openness and physical activity was moderated such that studies imposing experimental demand exhibited larger effects ($\beta$ = -.3662, SE = .0144, $z$ = -2.82, $p$ = .0047). A 2 way interaction was observed for gender and physical activity measurement quality ($z$ = 2.45, $p$ = .0143), Effects from studies that sampled females and used a validated measure of physical activity were smaller than effects from all other studies ($z$ = -2.91, $p$ = .0036).

In the multi-level model, the effect of experimental demand was not significant ($z$ = 0.541, $p$ = .589), but the interaction between gender and use of a validated measure of physical activity remained significant ($z$ = 2.24, $p$ = .025). Model fit ($\chi^2$ (5) = 175.8, BIC = 180) was improved compared to the intercept-only model ($\Delta \chi^2$ (3) = 61.5, $p$ < .0001, BIC 180 vs. 187).

**Moderator analyses: Agreeableness.** Gender, age and clinical status were significant univariate moderators of the relationship between Agreeableness and physical activity. The relationship was small and positive among females ($r$ = .0308; 95% CI = .0045, .0571; $p$ < .05), whereas among adults ages 35-65 years and also among clinical samples it was small and negative ($r$ = -.0407; 95% CI = -.0620, -.0193; $p$ <.001, and $r$ = -.0847; 95% CI = -.1517, -.0168; $p$ < .05, respectively). Modeled together in multiple regression analysis, age group remained significant ($\beta$ = -.3718, $z$ = -2.64, $p$ = .0082), but gender ($\beta$ = -.1555, $z$ = -1.15, $p$ = .2499) and clinical status $\beta$ = -.2035, $z$ = -1.51, $p$ = .1304) were no longer significant. Tests for 2 way interactions were not significant ($p$ > .05).

In the multi-level model, the effect of age group remained significant ($z$ = - 4.06, $p$ < .0001). Model fit ($\chi^2$ (5) = 130.2, BIC = 134) was improved compared to the intercept-only model ($\Delta \chi^2$ (3) = 44.7, $p$ < .0001, BIC was 134 vs. 169). The residual variance was .001 (SE= .001, $z$ = 1.40, $p$ = .161), indicating that 50% of the variance between effects was explained by the conditional model.

## Discussion

The associations of physical activity with Extraversion, Neuroticism, and Conscientiousness reported here are consistent with, but smaller than, correlations reported in a prior review of a smaller number of studies (Rhodes & Smith, 2006). Reasons for the difference in effect sizes between studies are unclear, but likely include the larger number of included effects and lack of adjustment for measurement error in this study. Here we also provide new evidence for a small but significant relationship between physical activity and Openness. The observations are theoretically plausible. Higher levels of physical activity among Extraverts may fulfill a drive for stimulation and socialization. It has been suggested (Eysenck et al., 1982) that the link between Extraversion and physical activity results from a heightened tendency to seek out strong sensory stimulation (such as physical activities) among Extraverts, whereas Introverts tend to avoid it. Also, Extraverts are typically very social and outgoing, which may increase their likelihood of exposure to settings that offer opportunities to be physically active. In contrast, individuals scoring high on Neuroticism exhibit heightened anxiety, vulnerability and self-consciousness, which may inhibit their willingness to act on, or reduce their exposure to opportunities to be physically active. Neuroticism is also related to heightened autonomic responsiveness to intense stimuli, and a predisposition for negative affect (Eysenck, 1967; Gray, 1991), which could explain lower levels of physical activity if the physiological response of increased arousal during exercise is perceived negatively. Conscientious persons are characterized as deliberate and disciplined, they have a strong sense of duty, and are more likely to adhere to a variety of health behaviors (Bogg & Roberts, 2004), supporting the positive relationship with physical activity level observed here. Those with high levels of Openness are usually receptive to ideas and opportunities for new experiences, and are often willing to try new things; such individuals may be more likely to engage in different types of physical activity and more frequently than people who score low on Openness.

Associations between physical activity and all five personality traits were heterogeneous. Funnel plots for each trait (see Figures 2.7-2.11) corroborate this observation, displaying outlying effects. Tests of funnel plot asymmetry indicated that effects for all traits, except for Agreeableness, were significantly biased, though a conservative sensitivity analysis confirmed that significant mean effects remained after excluding outlying effects. Though funnel plot asymmetry is commonly interpreted as an indication of publication bias (Sterne & Harbord, 2004), an alternative possibility is that the size of the relationships between personality traits and physical activity might truly differ according to other characteristics of people, environmental contexts, or features of the methods used in the studies we reviewed here. Our moderator analyses helped to clarify the heterogeneity of effects for physical activity and all five traits. A staged approach to moderator analyses was conducted to provide an in depth understanding of the effects reported in the literature. The progression from univariate, to multivariate and finally multi-level analyses of moderators permits a clearer interpretation of true moderators as opposed to apparent moderators confounded by other variables or by correlated effects. Though we were able to code for and test several pertinent moderator variables, an inquiry into differences according to physical activity mode or setting was precluded by the absence of such information in the accumulated evidence. Important differences may exist in the type of physical activity preferred and possible interactions with environmental prompts or barriers for people of differing personalities.

Sample characteristics and study features moderated the association between personality traits and physical activity behavior, but they were frequently not substantiated after multi-level analyses. Effects for Extraversion and Neuroticism both appeared to be significantly moderated by an interaction between gender and geographic region. In both cases, European females seemed responsible for the interaction. However, multi-level analyses revealed that these observations were due to correlated effects. Initial results suggested that the positive relationship between physical activity and Extraversion was weakened among European females, whereas the negative association with Neuroticism was strengthened. Of the 15 Extraversion effects reported for North American females, 13 were nested within studies. Additionally, only four effects for

European females were retrieved for Extraversion, and five were retrieved for Neuroticism. Though gender differences in personality are replicable across cultures (Costa, Terracciano, & McCrae, 2001), physical activity and its difference between genders vary widely between countries (Bauman et al., 2009). Moderation by an interaction between gender and geographic region could be driven by international differences in physical activity level between genders. Though our final results support the absence of a gender by region interaction, there is currently too little evidence to confidently rule it out. Small effect sizes between personality and physical activity, coupled with the small number of independent effects retrieved and the relevance of gender and nation to physical activity level and personality call for more gender specific international research to strengthen this evidence, and confirm or refute this observation.

Correlations between physical activity and both Neuroticism and Openness were significantly moderated by an interaction between gender and physical activity measurement quality, though moderation remained only for Openness in the multi-level analysis. Planned contrasts demonstrated an inflation of the relationship between physical activity and Openness in studies of females measured with poor quality physical activity instruments, emphasizing the importance of using a validated measure of physical activity. The absence of effect moderation by physical activity measurement quality among males may indicate that males more reliably estimate their physical activity level than do females regardless of the quality of physical activity self-report. Perhaps a more detailed and structured self-report is required to properly estimate physical activity among females with sufficient sensitivity to accurately observe the small relationships between physical activity and personality.

In addition to sample characteristics, the relationship between physical activity and personality appears sensitive to methodological features. This is especially true for the association between physical activity and Conscientiousness which was moderated by experimental demand, and an interaction between physical activity measurement quality and personality item format. Effects were inflated by the inclusion of a measure of intention (i.e. experimental demand), and among studies using an unvalidated physical activity measure with a personality measure with statement or question item format. Conversely, use of unvalidated physical activity measures in conjunction with personality measures in adjective checklist format seemed to reduce the mean effect, suggesting a polarizing effect of poor physical activity measurement on the observed correlation according to personality item format. Though this is an appealing challenge to explain on theoretical grounds, this interaction is driven by a single effect retrieved for Conscientiousness that uses an unvalidated physical activity measure and an adjective checklist. Rather than call for more studies using a less desirable measurement format, perhaps future studies might utilize both kinds of measures for each construct to empirically test this possibility. This seems a better route than to encourage studies using poor quality measures independently to gradually build up the evidence. Additional work is therefore needed to clarify the possibility of this peculiar interaction, so as to inform researchers in their methodological choices and to minimize false inflation of effects resulting from study designs.

The notion of experimental demand herein is conceptually reflective of a bias commonly termed the Rosenthal effect, or the Pygmalion effect (Pfungst, 1911; Rosenthal & Jacobson, 1968). Though most commonly discussed in reference to participant performance relative to some form of imposed expectation (such as academic performance and teacher expectation), this bias could also apply to physical activity behavior in studies which ask participants to report how active they intend to be prior to the period during which physical activity is measured. Our results suggest that this possibility is specifically relevant for individuals scoring high for

Conscientiousness. Because conscientious people are predisposed to dutifully carry out plans (i.e. intentions), it could be expected that the act of stating their intention for physical activity functions as a prompt for them to follow through on those plans. Further support is found in a recent systematic review (Rhodes & Dickau, 2013) in which Conscientiousness is suggested to moderate the intention/behavior relationship as it relates to physical activity. This is essentially the same effect we describe, though from a different perspective and with less evidence. Taken together, these observations suggest that employing a record of intention among conscientious persons may enhance intervention efficacy by acting as a prompt. Evidence opposing this suggestion comes from a recent meta-analysis reporting a small non-significant effect for the technique "prompting intention formation," on efficacy of health behavior interventions (Michie, Abraham, Whittington, McAteer, & Gupta, 2009). However, this evidence is limited in several ways. Effects for different target behaviors were analyzed together likely confounding the results, the extent of variation in the application of this technique (e.g. self-report, interview, daily log, etc.) is unreported, and personality was not considered as a potential moderator, further validating additional research testing the interplay between Conscientiousness, measures of intention and physical activity level.

Effects for Extraversion were moderated by an interaction between gender and experimental demand. More research is needed to clarify this moderation as only 3 effects were retrieved for Extraversion among samples of females responding to measures of intention. A plausible reason for gender differences in the impact of reporting intention on the relationship between Extraversion and physical activity is unclear. It is possible that, because women report higher levels of Conscientiousness than men (Costa et al., 2001) this interaction could be confounded with the influence of Conscientiousness. An interaction between Conscientiousness and Extraversion has been explored elsewhere (Witt, 2002), though not relative to physical activity level. A conceptual theory for the interaction of personality dimensions has been elaborated in the AB5C big five personality circumplex, which consists of ten two-dimensional circumplexes that consider all possible pairs of big five dimensions as coordinates in conceptual space (Hofstee, De Raad, & Goldberg, 1992), though it has received relatively little attention.

The moderation of effects for Extraversion and Neuroticism by study design reported in the previous meta-analysis (Rhodes & Smith, 2006) as favoring prospective studies was not present in the analysis we report here. It is possible that those earlier observations were confounded by experimental demand within the prospective designs among the smaller number of retrieved effects in the prior analysis (Rhodes & Smith, 2006). The presumed Rosenthal effect on physical activity behavior imposed by a measure of intention has yet to be empirically tested, making a conclusive statement as to the nature of this artifact premature. Experiments to test the effect of measuring intention prior to measuring physical activity should be conducted, and personality should be considered as a covariate, particularly Conscientiousness.

The relationship between Extraversion and physical activity was also moderated by the operational definition of physical activity across studies. Results suggest that this effect is intensity dependent. This is a logical observation in consideration of the lower order facets of Extraversion. It has been suggested that this relationship may be driven completely by the lower order facet Activity (Rhodes, Courneya, & Jones, 2002). The Activity facet is reflected in “rapid tempo and vigorous movement, in a sense of energy, and in a need to keep busy” (Costa & McCrae, 1992). It is easy to see how these qualities may influence the relationship between Extraversion and physical activity to be intensity dependent. This quality may explain why effects are weaker among physical activity measures capturing mild to moderate physical activity than among measures for any other physical activity construct. It is also plausible that the lower order facet Excitement Seeking influences the relationship between Extraversion and physical activity mode, as excitement seekers may be more likely to engage in activities with higher risk (Freixanet, 1991). Such an effect could also be expected to influence physical activity intensity, frequency and/or duration indirectly through physical activity mode. Little work has been done to clarify the relationship between physical activity and the spectrum of lower order facets contributing to the Big Five (Rhodes & Pfaeffli, 2012), though such clarification may be key to identifying important sources of variation in the associations between physical activity and primary personality.

Though the population effect of physical activity and Agreeableness was not significant, moderator analysis suggests that this relationship is dependent on age. Of the 52 effects for Agreeableness, 27 were from samples <25 years old, 6 were from samples 25-34 years old, 10 came from samples between 45-54 years old, and 2 were from samples ≥55 years old. Our criteria for moderator levels stated that each level must have at least 10 effects to be included. Out of a desire to retain as many effects as possible for moderator analyses, we collapsed groups into a dichotomy representing samples < or > 35 years old. Significant results for a negative relationship were observed for samples >35 years, but not <35 years of age. Agreeableness is very stable across the lifespan, only changing significantly with an increase after age 50 (Roberts et al., 2006), and physical activity after age 35 remains relatively stable through middle adulthood with a small increase around retirement age before a steady decline during the final stage of life (Caspersen et al., 2000). The negative association between these constructs among samples greater than 35 years old may be driven by the simultaneous increase in Agreeableness after age 50 and the steady decline of physical activity in the final stage of life. Of the 14 effects for samples greater than 35 years old, 8 came from samples with a mean age greater than 50 years. On the other hand, this moderation may also be the result of a confounding variable. Additional work is needed to clarify the impact of age on the relationship between physical activity and Agreeableness, and to test for possible confounding variables.

Perhaps the most compelling finding herein was the independence of the relationship between physical activity and Neuroticism. After controlling for correlations between nested effects, not a single significant moderator was observed. Neuroticism is one of the most extensively studied personality dimensions in reference to physical activity behavior, and predisposes individuals to the development of mental disorders (Beard et al., 2007) which are significantly improved with physical activity (Herring, O'Connor, et al., 2010; North, McCullagh, & Tran, 1990). These clear relationships between personality, physical activity and mental health support the notion that personality could modify the relationship between physical activity and mental health, as suggested elsewhere (De Moor et al., 2006). Though it was the least heterogeneous of the significant effects found, it still exhibits moderate heterogeneity, suggesting the presence of confounding variables. Research is needed to assess the possibility that the observed heterogeneity in the effect between Neuroticism and physical activity could result from individual differences in other personality dimensions, or features not considered here.

**Limitations.** Limited statistical power to detect interactions, particularly 3-way interactions, resulted from the relatively small number of studies that reported on common or similarly defined moderator factors for each trait. This is particularly relevant to the impact of study features on the relationship between Conscientiousness and physical activity. Multiple 2-way interactions and diversity in the measurement and conceptualization of physical activity and personality among these studies support the possibility of more complex interactions for which there is insufficient evidence to test. This study is also limited by our inability to correct for measurement error (Hunter & Schmidt, 2004), as test-retest reliability was reported for less than 1% of the physical activity measures, and for none of the personality measures used in studies included in the present analysis. Reference to a validation publication for the test-retest reliability of physical activity and personality measures was observed for 13% and 1%, respectively, of the included studies. Internal consistency was reported for only 11% of the physical activity measures and 58% of the personality measures among retrieved effects, and an additional 4% cited a validation publication for the personality measure used. Though the correction for measurement error was reported in the previous meta-analysis (Rhodes & Smith, 2006) the reliability estimates used were not, rendering our observations incomparable to that analysis. We were also unable to test moderator variables reflective of physical activity mode and setting due to insufficient reporting in the literature. It is likely that personality influences the type of physical activity in which one participates, as well as how one responds to environmental prompts or barriers for physical activity. Lastly, it is possible that the correlation between one trait and physical activity is influenced by the mean score for a different trait within individuals. An examination of moderation by sample mean personality scores on the observed relationship between each trait and physical activity may further clarify the observed widespread heterogeneity of effects, but was beyond the scope of this analysis. The possibility of complex interactions between primary personality traits influencing physical activity level is consistent with personality theory, and deserves an independent examination.

**Conclusion.** In conclusion, the available evidence supports a significant relationship between physical activity and the traits Extraversion, Neuroticism, Conscientiousness, and

Openness. Effects were heterogeneous and, except for Neuroticism, were moderated by characteristics of the sample or study features. Interactions influencing these relationships suggest that more complex moderation may be present in some cases, though more evidence is needed to appropriately assess this possibility. Analyses also support an age dependent relationship between physical activity and Agreeableness. Physical activity and personality are dynamic constructs. Traits should not be expected to contribute to physical activity uniformly. It is important to test relationships between physical activity and personality in terms of the dimension of physical activity expected to reflect individual differences in the trait of interest (e.g. Excitement Seeking is likely to influence mode, whereas Self-Discipline is likely to influence frequency). In addition to age and gender, psychological constructs (e.g. other traits) and environmental influences (e.g. physical activity exposure and culture) are expected to moderate or possibly mediate the relationship between physical activity and personality, and should be identified and described. Variation in the measurement and conceptualization of physical activity and personality limits our ability to more accurately describe their true relationships, and highlights the lack of a consistent research paradigm in these fields and the challenges presented for cross study comparisons.

The use of objective physical activity measures to capture frequency, duration and intensity, preferably in conjunction with a self-report of physical activity mode among studies exploring physical activity and personality is recommended, as are prospective study designs, so that we may more precisely conceptualize how personality influences the development of habitual physical activity. Detailed descriptions of samples and more work examining associations of lower order traits and physical activity are encouraged to facilitate a better understanding of physical activity as a behavioral domain that manifests personality differences as well as the application of personality theory by interventionists and clinicians seeking to increase physical activity.

The relationship between personality and physical activity may modify the widely reported relationship between physical activity and mental health outcomes. Because the observable effect between physical activity and personality is small, large samples will be required to test these possibilities. Also, advances in behavioral genetics will surely inform our understanding of the link between primary personality and habitual physical activity. Research examining potential pleiotropic mechanisms linking physical activity to primary personality is needed (Dishman, 2008). Further studies might also consider advancements in biologically driven conceptualizations of personality, such as punishment and reward sensitivity (Gray, 1982, 1991; Gray & McNaughton, 2000), and their interaction with reinforcement history in physical activity settings.

Table 2.1.
*Description of included studies.*
XS = cross-sectional; PRO = prospective; CS = college students; Neth = Netherlands; E = Extraversion; N = Neuroticism; C = Conscientiousness; O = Openness; A = Agreeableness; B = both genders; F = females only; M = males only; PA = physical activity; SR = self-report; NS-AA = nonspecific or author adapted; Freq = frequency; Q1 = general quantity; Q2 = quantity of moderate to vigorous; Q3 = quantity of mild to moderate; Vol = volume
*Experimental demand

| Studies | N | Effects | Design | Sample Type | Nation | Dimension | Gender | PA Measure | PA Definition |
|---|---|---|---|---|---|---|---|---|---|
| Adams & Nettle, 2009 | 418 | 30 | XS | Adults | US | E, N, C, O, A | M, F, B | Single item SR | Q3, Q2 |
| Arai & Hisamicha, 1998 | 22448 | 4 | XS | Adults | Japan | E, N | M, F | NS-AA SR | Freq |
| Armon et al., 2012 | 1709 | 5 | PRO | Adults | Israel | E, N, C, O, A | B | NS-AA SR | Freq |
| Armon & Shirom, 2011 | 1217 | 10 | XS & PRO | Adults | Israel | E,N,C,O,A | B | Single item SR | Q3 |
| Bogg et al., 2008 | 201 | 5 | XS | CS | US | E,N,C,O,A | B | Epidemiology SR | Dichotomy |
| Buchman et al., 2013 | 983 | 2 | PRO | Adults | US | E, N | B | Epidemiology SR | Dichotomy |
| Burke et al., 1992 | 843 | 3 | XS | Adults | Australia | E | M, F, B | NS-AA SR | Freq |
| Chatzisarantis et al, 2008 * | 180 | 5 | PRO | CS | UK | E,N,C,O,A | B | NS-AA SR | Freq |
| Conner et al., 2007 * | 146 | 3 | XS & PRO | CS | Canada | C | B | Godin LTEQ | Vol |
| Conner & Abraham, 2001 * | 123 | 12 | PRO | CS | UK | E,N,C,O,A | B | NS-AA SR | Freq |
| Courneya & Hellsten, 1998 | 264 | 20 | XS | CS | Canada | E,N,C,O,A | F | Godin LTEQ, and a single item SR | Vol and Freq |
| Courneya et al., 2002 * | 51 | 3 | PRO | Cancer survivors | Canada | E, N, O | B | Adherence record | Freq |
| Courneya et al., 1999 * | 367 | 10 | XS | CS, aerobics participants | Canada | E,N,C,O,A | F | Godin LTEQ | Vol |
| Daugherty & Brase, 2010 | 467 | 5 | XS | CS | US | E,N,C,O,A | B | Single item SR | Q1 |
| Davies et al., 2010 * | 74 | 5 | XS | Diabetics | Australia | E,N,C,O,A | B | Godin LTEQ | Vol |
| Davis & Cerullo, 1996 | 167 | 2 | XS | CS | Canada | E, N | F | Interview | Q1 |
| de Bruijn et al., 2009 * | 313 | 8 | XS & PRO | Adults | Neth | E, C | B | Dutch IPAQ | Q2, Q3 |
| de Bruijn et al., 2005 | 825 | 10 | XS | Children & adolescents | Neth | E,N,C,O,A | B | NS-AA SR | Q3, Q2 |
| de Moor et al., 2006 | 35165 | 2 | PRO | Adults & adolescents | Neth | E, N | B | NS-AA SR | Dichotomy |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Eagleton et al., 2007 | 90 | 2 | XS | CS | Canada | E, N | B | NS-AA SR | Dichotomy |
| Ebstrup et al., 2013 | 3222 | 5 | XS | Adults | Denmark | E,N,C,O,A | B | PAS-2 | Q2 |
| Elvasky & McAuley, 2009 | 157 | 1 | XS | Menopausal women | US | N | F | Epidemiology SR | Vol |
| Giacobbi et al., 2005 | 108 | 5 | PRO | CS | US | E,N,C,O,A | B | PA Diary | Vol |
| Harma et al., 1988 | 128 | 2 | XS | Hospital shift workers | Finland | E, N | F | NS-AA SR | Q1 |
| Hausenblas et al., 2004 | 390 | 5 | XS | CS | US | E,N,C,O,A | B | Godin LTEQ | Vol |
| Hendry, 1975 | 220 | 4 | XS | CS | Scotland | E, N | M, F | NS-AA SR | Dichotomy |
| Herrera et al., 1995 | 25 | 3 | XS | CS | Spain | E, N | F | NS-AA SR | Dichotomy |
| Hilleras et al., 1999 | 102 | 2 | XS | Older adults | Sweden | E, N | B | Interview | Q1 |
| Ingledew et al., 2004 | 209 | 5 | XS | Sports centre attendees | UK | E,N,C,O,A | B | Single item SR | Dichotomy |
| Ingledew & Markl&, 2008 | 249 | 5 | XS | Office workers | UK | E,N,C,O,A | B | Epidemiology SR | Vol |
| Jette, 1975 | 73 | 1 | PRO | Adults | Canada | E | M | NS-AA SR | Dichotomy |
| Kern et al., 2010 | 1012 | 12 | XS | Adults | US | E, N, C, A | M, F, B | NS-AA SR | Vol |
| Kirkcaldy & Furnam, 1991 | 191 | 3 | XS | CS | Germany | E, N | B | Kirkcaldy's Recreational Interest Inventory | Dichotomy |
| Kull et al., 2012 | 919 | 5 | XS | Adults | Estonia | E,N,C,O,A | F | GPAQ | Vol |
| Lemos-Giraldez et al., 1997 | 1184 | 5 | XS | CS | Spain | E,N,C,O,A | B | NS-AA SR | Dichotomy |
| Lewis & Sutton, 2011 | 100 | 5 | XS | CS | UK | E,N,C,O,A | B | Single item SR | Freq |
| Lobstein et al., 1989 | 36 | 1 | XS | Adults | US | N | M | NS-AA SR | Dichotomy |
| Lochbaum, et al., 2002 | 53 | 1 | XS | CS | US | O | B | NS-AA SR | Dichotomy |
| Lochbaum et al., 2012 | 213 | 6 | XS | Adults | US | E, N | B | Godin LTEQ | Vol, Q2, Q3 |
| Lochbaum et al., 2010 | 1484 | 20 | XS | CS | US | E,N,C,O,A | M, F | Godin LTEQ | Q2, Q3 |
| Marks & Lutgendorf, 1999 | 97 | 2 | XS | Older adults | US | N, C | B | Personal Lifestyle Questionnaire | Freq |
| Martin et al., 2006 | 174 | 1 | XS | Older adults | US | E | B | Single item SR | Dichotomy |
| Massie & Shephard, 1971 | 49 | 3 | PRO | Adults | Canada | E, N | M | Adherence record | Freq |
| McEachan et al., 2010 * | 397 | 2 | PRO | Academics | UK | E, C | B | Single item SR | Q2 |
| Ohmori et al., 2007 | 235 | 20 | PRO | Obese adults | Japan | E,N,C,O,A | M, F | Accelerometer | Q1 |
| Parkes, 2006 | 314 | 1 | PRO | Offshore workers | UK | N | M | Frequency of facility use | Freq |
| Potgieter & Venter. 1995 | 116 | 2 | PRO | Academics | South Africa | E, N | B | Frequency of facility use | Dichotomy |
| Reed et al., 2013 | 1165 | 2 | XS | Academics | US | C | B | SR TTM | Dichotomy |
| Renfrow & Bolton, 1979 | 46 | 1 | XS | University faculty | US | E | M | NS-AA SR | Dichotomy |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Rhodes & Courneya, 2003* | 300 | 5 | PRO | CS | Canada | E,N,C,O,A | B | Godin LTEQ | Q2 |
| Rhodes et al., 2007* | 203 | 3 | PRO | Adults | Canada | E, N, C | B | Godin LTEQ | Freq |
| Rhodes et al., 2001 | 175 | 10 | XS | Breast cancer patients & survivors | Canada | E,N,C,O,A | F | SR TTM | Dichotomy |
| Rhodes et al., 2003 * | 602 | 10 | PRO | CS, & Cancer survivors | Canada | E,N,C,O,A | B | Godin LTEQ | Q2 |
| Rhodes, et al. 2002 * | 312 | 5 | PRO | CS | Canada | E,N,C,O,A | F | Single item SR | Freq |
| Saklofske et al., 2007 | 497 | 15 | XS | CS | Canada | E,N,C,O,A | B | NS-AA SR | Vol, Freq, Q1 |
| Sale et al., 2002 | 187 | 2 | XS | CS | UK | E, N | B | Single item SR | Q1 |
| Sevcikova et al., 2000 | 213 | 2 | XS | Children & adolescents | Slovakia | N | M, F | NS-AA SR | Dichotomy |
| Smith & Storandt, 1997 | 246 | 5 | XS | Older adults | US | E,N,C,O,A | B | NS-AA SR | Dichotomy |
| Szabo, 1992 | 35 | 2 | XS | CS | Canada | E, N | B, F | Interview | Dichotomy |
| Tolea et al., 2012 | 1220 | 3 | XS | Adults | US | E, N, C | B | Epidemiology SR | Dichotomy |
| Walsh et al., 2005 | 80 | 1 | XS | Adults | UK | C | B | Single item SR | Q2 |
| Wheeler et al., 2012 | 28 | 5 | XS | Diabetics | US | E,N,C,O,A | B | NS-AA SR | Freq |
| Wilson et al., 2005 | 6158 | 2 | PRO | Older adults | US | E, N | B | Epidemiology SR | Q1 |
| Yeung & Hemsley, 1997 | 252 | 2 | XS | Adults | England | E, N | B | Single item SR | Q1 |

Table 2.2.

*The relationship between physical activity and Extraversion: Mean Effects and heterogeneity coefficients.*

[a] Significant at $p$<.05. [b] Significant at $p$<.01. [c] Significant at $p$<.001. [d] Significant at $p$<.0001.
*Significant univariate moderation.

| | Contrast Weight | N | Mean ES | 95%CI | Q | $I^2$ |
|---|---|---|---|---|---|---|
| Overall Mean ES | | 88 | .1076[d] | [.0914,.1238] | 247.1632[d] | 65.20 |
| Gender | | | | | | |
| Females only | -1 | 23 | .1131[d] | [.0694, .1564] | 84.6093[d] | 75.18 |
| Males only | .5 | 13 | .0874[c] | [.0404, .1341] | 23.4549[a] | 53.10 |
| Both | .5 | 52 | .1100[d] | [.0904, .1294] | 138.5104[d] | 63.90 |
| Age | | | | | | |
| <25 yrs | 1 | 33 | .1373[d] | [.0955, .1786] | 154.9035[d] | 79.99 |
| 25-34 yrs | 2 | 15 | .1014[d] | [.0685, .1341] | 29.0504[a] | 55.25 |
| 35-44 yrs | 3 | 7 | .0579 | [-.0036, .1190] | 4.8078 | 0 |
| 45-54 yrs | 4 | 15 | .0842[d] | [.0593, .1090] | 24.5777[a] | 47.11 |
| ≥55 yrs | 5 | 9 | .1035[d] | [.0739, .1329] | 11.8389 | 40.87 |
| Sample Type | | | | | | |
| Clinical Sample | 1 | 10 | .1345[b] | [.0508, .2163] | 12.6928 | 36.97 |
| Nonclinical Sample | -1 | 78 | .1062[d] | [.0896, .1227] | 233.3032[d] | 67.42 |
| Geographic Region* | | | | | | |
| North America | 1 | 49 | .1356[d] | [.1079, .1630] | 156.9391[d] | 70.05 |
| Europe | -1 | 28 | .0696[d] | [.0420, .0972] | 80.8501[d] | 67.84 |
| East Asia [Japan only] | | 6 | .1135[d] | [.0959, .1310] | 3.2637 | 0 |
| Study Design | | | | | | |
| Cross-sectional | 1 | 63 | .1018[d] | [.0845, .1190] | 120.9784[d] | 49.58 |
| Prospective/Longitudinal | -1 | 25 | .1198[d] | [.0819, .1575] | 120.7949[d] | 80.96 |
| PA Tool | | | | | | |
| Unvalidated Self-Report | -1 | 52 | .1080[d] | [.0909, .1249] | 101.5452[d] | 50.76 |
| Validated Self-Report | .5 | 27 | .1077[d] | [.0697, .1454] | 131.0880[d] | 80.93 |
| Objective Measure | .5 | 9 | .0988[a] | [.0101, .1860] | 9.9822 | 29.88 |
| PA Definition* | | | | | | |
| Volume | | 18 | .1097[d] | [.0699, .1492] | 42.7075[c] | 62.54 |
| General Quantity | | 12 | .1005[d] | [.0581, .1426] | 27.8181[b] | 64.05 |
| Quantity of Moderate to Vigorous | | 14 | .1377[d] | [.0944, .1805] | 78.5843[d] | 84.73 |
| Quantity of Mild to Moderate | | 11 | .0423[b] | [.0134, .0712] | 9.6688 | 6.92 |
| Frequency | | 8 | .0119 | [-.0790, .1025] | 18.2401[a] | 67.11 |
| Dichotomy | | 17 | .0871[d] | [.0435, .1304] | 26.6354[a] | 43.68 |
| Personality Measure Item Format | | | | | | |
| Adjective | -1 | 18 | .0928[d] | [.0470, .1383] | 72.8412[d] | 78.03 |
| Statement/Question | 1 | 70 | .1116[d] | [.0945, .1287] | 166.5678[d] | 59.18 |
| Experimental Demand* | | | | | | |
| Yes | -1 | 15 | .1835[d] | [.1030, .2617] | 75.9486[d] | 82.88 |
| No | 1 | 73 | .0948[d] | [.1094, .1094] | 147.7734[d] | 51.95 |

Table 2.3.
*The relationship between physical activity and Neuroticism: Mean Effects and heterogeneity coefficients.*
[a] Significant at *p*<.05. [b] Significant at *p*<.01. [c] Significant at *p*<.001. [d] Significant at *p*<.0001.
*Significant univariate moderation.

| | Contrast Weight | N | Mean ES | 95%CI | Q | $I^2$ |
|---|---|---|---|---|---|---|
| Overall Mean ES | | 82 | -.0710[d] | [-.0867, -.0554] | 188.0551[d] | 57.46 |
| Gender | | | | | | |
| Females only | -1 | 25 | -.0720[c] | [-.1102, -.0335] | 64.0027[d] | 64.06 |
| Males only | .5 | 13 | -.0546[d] | [-.0772, -.0320] | 12.0331 | 8.59 |
| Both | .5 | 44 | -.0762[d] | [-.0962, -.0561] | 109.7146[d] | 61.72 |
| Age | | | | | | |
| <25 yrs | 1 | 35 | -.0683[d] | [-.1109, -.0509] | 81.3290[d] | 59.42 |
| 25-34 yrs | 2 | 10 | -.0803[d] | [-.1121, -.0483] | 13.6114 | 41.23 |
| 35-44 yrs | 3 | 6 | -.0920 | [-.2204, .0395] | 22.8163[c] | 82.47 |
| 45-54 yrs | 4 | 16 | -.0471[d] | [-.0697, -.0245] | 22.7203 | 38.38 |
| ≥55 yrs | 5 | 7 | -.0714[a] | [-.1304, -.0118] | 21.2217[b] | 76.44 |
| Sample Type | | | | | | |
| Clinical Sample | 1 | 11 | -.0336 | [-.1109, .0441] | 14.2557 | 36.87 |
| Nonclinical Sample | -1 | 71 | -.0729[d] | [-.0889, -.0569] | 173.0697[d] | 60.13 |
| Geographic Region* | | | | | | |
| North America | 1 | 49 | -.0929[d] | [-.1148, -.0710] | 95.8006[d] | 50.94 |
| Europe | -1 | 25 | -.0434[c] | [-.0686, -.0182] | 50.5683[b] | 54.52 |
| East Asia [Japan only] | | 6 | -.0462[b] | [-.0776, -.0147] | 7.3373 | 45.48 |
| Study Design | | | | | | |
| Cross-sectional | 1 | 60 | -.0719[d] | [-.0905, -.0532] | 120.8647[d] | 52.01 |
| Prospective/Longitudinal | -1 | 22 | -.0689[d] | [-.1019, -.0356] | 66.8650[d] | 70.90 |
| PA Tool | | | | | | |
| Unvalidated Self-Report | -1 | 49 | -.0744[d] | [-.0897, -.0590] | 72.5221[a] | 35.19 |
| Validated Self-Report | .5 | 24 | -.0627[b] | [-.1004, -.0248] | 101.3410[d] | 78.29 |
| Objective Measure | .5 | 9 | -.0200 | [-.1101, .0704] | 10.2800 | 31.91 |
| PA Definition | | | | | | |
| Volume | | 16 | -.0425 | [-.0910, .0062] | 42.3820[c] | 66.97 |
| General Quantity | | 12 | -.0922[d] | [-.1372, -.0469] | 31.7232[c] | 68.48 |
| Quantity of Moderate to Vigorous | | 15 | -.0825[d] | [-.1178, -.0470] | 36.4976[c] | 64.38 |
| Quantity of Mild to Moderate | | 9 | -.0421[a] | [-.0818, -.0022] | 11.7717 | 40.54 |
| Frequency | | 14 | -.0784[d] | [-.1098, -.0469] | 19.0381 | 36.97 |
| Dichotomy | | 16 | -.0704[c] | [-.1092, -.0313] | 20.9306 | 33.11 |
| Personality Measure Item Format | | | | | | |
| Adjective | -1 | 11 | -.0405[c] | [-.0624, -.0185] | 8.9191 | 0 |
| Statement/Question | 1 | 71 | -.0776[d] | [-.0957, -.0595] | 173.5681[d] | 60.25 |
| Experimental Demand | | | | | | |
| Yes | -1 | 12 | -.0982[b] | [-.1567, -.0390] | 21.2411[a] | 52.92 |
| No | 1 | 70 | -.0671[d] | [-.0832, -.0509] | 162.3349[d] | 58.11 |

Table 2.4.

*The relationship between physical activity and Conscientiousness: Mean Effects and heterogeneity coefficients.*

[a] Significant at $p<.05$. [b] Significant at $p<.01$. [c] Significant at $p<.001$. [d] Significant at $p<.0001$.
*Significant univariate moderation.

| | Contrast Weight | N | Mean ES | 95%CI | Q | $I^2$ |
|---|---|---|---|---|---|---|
| Overall Mean ES | | 69 | .1037[d] | [.0837, .1237] | 170.3278[d] | 60.66 |
| Gender | | | | | | |
| Females only | -1 | 17 | .1351[d] | [.0983, .1716] | 27.6941[a] | 45.84 |
| Males only | .5 | 7 | .0897[d] | [.0492, .1298] | 3.8008 | 0 |
| Both | .5 | 45 | .0954[d] | [.0702, .1206] | 126.2417[d] | 65.94 |
| Age | | | | | | |
| <25 yrs | 1 | 28 | .1221[d] | [.0846, .1592] | 108.1114[d] | 75.95 |
| 25-44 yrs | 2 | 16 | .1021[d] | [.0678, .1360] | 26.5376[a] | 46.88 |
| ≥45 yrs | 3 | 14 | .0579[d] | [.0308, .0849] | 17.1518 | 30.04 |
| Sample Type | | | | | | |
| Clinical Sample | 1 | 9 | .1332[c] | [.0633, .0633] | 8.6114 | 18.71 |
| Nonclinical Sample | -1 | 60 | .1017[d] | [.0809, .1224] | 159.3303[d] | 63.60 |
| Geographic Region | | | | | | |
| North America | 1 | 42 | .1038[d] | [.0822, .1254] | 69.6017[b] | 42.53 |
| Europe | -1 | 22 | .1025[d] | [.0637, .1410] | 85.4640[d] | 76.60 |
| Study Design* | | | | | | |
| Cross-sectional | 1 | 47 | .0843[d] | [.0638, .1047] | 93.7585[d] | 52.00 |
| Prospective/Longitudinal | -1 | 22 | .1526[d] | [.1044, .2001] | 68.2672[d] | 70.70 |
| PA Tool | | | | | | |
| Unvalidated Self-Report | -1 | 38 | .1005[d] | [.0715, .1294] | 123.2487[d] | 70.79 |
| Validated Self-Report | .5 | 25 | .1118[d] | [.0861, .1374] | 36.6493[a] | 37.24 |
| Objective Measure | .5 | 6 | .0846 | [-.0015, .1695] | 1.9260 | 0 |
| PA Definition* | | | | | | |
| Volume | | 17 | .0787[d] | [.0437, .1134] | 24.2311 | 38.10 |
| General Quantity | | 5 | .0672 | [-.0014, .1352] | 8.4111 | 64.33 |
| Quantity of Moderate to Vigorous | | 18 | .1168[d] | [.0763, .1568] | 65.1076[d] | 75.43 |
| Quantity of Mild to Moderate | | 10 | .0887[d] | [.0490, .1282] | 14.7342 | 45.70 |
| Frequency | | 11 | .2136[d] | [.1342, .2901] | 27.0216[b] | 70.39 |
| Dichotomy | | 8 | .0552[c] | [.0232, .0870] | 6.1695 | 2.75 |
| Personality Measure Item Format* | | | | | | |
| Adjective | -1 | 15 | .0537[b] | [.0195, .0878] | 34.5423[b] | 62.36 |
| Statement/Question | 1 | 54 | .1208[d] | [.0982, .1433] | 113.0053[d] | 53.98 |
| Experimental demand* | | | | | | |
| Yes | -1 | 18 | .1994[d] | [.1591, .2391] | 27.4761 | 41.77 |
| No | 1 | 51 | .0719[d] | [.0544, .0894] | 83.0082[b] | 40.97 |

Table 2.5.

*The relationship between physical activity and Openness: Mean Effects and heterogeneity coefficients.*

[a] Significant at *p*<.05. [b] Significant at *p*<.01. [c] Significant at *p*<.001. [d] Significant at *p*<.0001.
*Significant univariate moderation.

| | Contrast Weight | N | Mean ES | 95%CI | Q | $I^2$ |
|---|---|---|---|---|---|---|
| Overall Mean ES | | 51 | .0344[b] | [.0128, .0560] | 102.8891[d] | 52.38 |
| Gender | | | | | | |
| Females only | -1 | 16 | .0074 | [-.0425, .0573] | 41.5860[c] | 66.33 |
| Males only | .5 | 6 | .0479[a] | [.0011, .0945] | 4.4248 | 9.60 |
| Both | .5 | 29 | .0449[c] | [.0208, .0690] | 48.7959[b] | 44.67 |
| Age | | | | | | |
| 14 to 35 yrs | 1 | 30 | .0295 | [-.0025, .0615] | 86.2884[d] | 67.55 |
| 35 to 65 yrs | 2 | 14 | .0245[a] | [.0032, .0458] | 9.5636 | 0 |
| Sample Type | | | | | | |
| Clinical Sample | 1 | 10 | .0591 | [-.0071, .1248] | 6.1216 | 0 |
| Nonclinical Sample | -1 | 41 | .0327[b] | [.0095, .0558] | 95.7300[d] | 59.26 |
| Geographic Region | | | | | | |
| North America | 1 | 33 | .0402[a] | [.0067, .0736] | 83.6161[d] | 62.93 |
| Europe | -1 | 13 | .0246[a] | [.0005, .0487] | 17.0145 | 35.35 |
| Study Design | | | | | | |
| Cross-sectional | 1 | 36 | .0227[a] | [.0001, .0453] | 63.3825[b] | 46.36 |
| Prospective/Longitudinal | -1 | 15 | .0694[b] | [.0166, .1218] | 33.6134[b] | 61.32 |
| PA Tool | | | | | | |
| Unvalidated Self-Report | -1 | 28 | .0374[c] | [.0180, .0567] | 32.5193 | 20.05 |
| Validated Self-Report | .5 | 16 | .0303 | [-.0214, .0818] | 62.9786[d] | 77.77 |
| Objective Measure | .5 | 7 | -.0128 | [-.0960, .0705] | 4.7709 | 0 |
| PA Definition | | | | | | |
| Volume | | 11 | .0000 | [-.0352, .0353] | 8.6666 | 0 |
| General Quantity | | 5 | .0169 | [-.0202, .0540] | 2.4693 | 0 |
| Quantity of Moderate to Vigorous | | 14 | .0358 | [-.0036, .0752] | 41.1016[d] | 70.80 |
| Quantity of Mild to Moderate | | 7 | .0723[a] | [.0043, .1397] | 22.5325[c] | 77.81 |
| Frequency | | 9 | .0664 | [-.0171, .1490] | 17.9174[a] | 60.93 |
| Dichotomy | | 5 | .0170 | [-.0430, .0770] | 3.2763 | 8.43 |
| Personality Measure Item Format | | | | | | |
| Adjective | -1 | 10 | .0485[a] | [.0092, .0877] | 25.2487[b] | 68.32 |
| Statement/Question | 1 | 41 | .0287[a] | [.0028, .0545] | 74.1580[c] | 47.41 |
| Experimental Demand* | | | | | | |
| Yes | -1 | 11 | .1001[b] | [.0282, .1710] | 25.6096[b] | 82.89 |
| No | 1 | 40 | .0203[a] | [.0004, .0402] | 62.9733[b] | 39.66 |

Table 2.6.
*The relationship between physical activity and Agreeableness: Mean Effects and heterogeneity coefficients.*
[a] Significant at $p$<.05. [b] Significant at $p$<.01. [c] Significant at $p$<.001. [d] Significant at $p$<.0001.
*Significant univariate moderation.

| | Contrast Weight | N | Mean ES | 95%CI | Q | $I^2$ |
|---|---|---|---|---|---|---|
| Overall Mean ES | | 52 | .0020 | [-.0169, .0208] | 90.0739[c] | 44.49 |
| Gender* | | | | | | |
| Females only | -1 | 17 | .0308[a] | [.0045, .0571] | 12.9243 | 0 |
| Males only | .5 | 7 | -.0228 | [-.0916, .0461] | 12.1347 | 58.80 |
| Both | .5 | 28 | -.0053 | [-.0305, .0199] | 55.9775[c] | 53.55 |
| Age* | | | | | | |
| 14 to 35 yrs | 1 | 33 | .0163 | [-.0035, .0362] | 44.1146 | 29.73 |
| 35 to 65 yrs | 2 | 12 | -.0407[c] | [-.0620, -.0193] | 8.1603 | 0 |
| Sample Type* | | | | | | |
| Clinical Sample | 1 | 9 | -.0847[a] | [-.1517, -.0168] | 5.5464 | 0 |
| Nonclinical Sample | -1 | 43 | .0073 | [-.0121, .0267] | 78.8997[c] | 48.04 |
| Geographic Region | | | | | | |
| North America | 1 | 34 | .0075 | [-.0154, .0303] | 49.7927[a] | 35.73 |
| Europe | -1 | 13 | -.0016 | [-.0307, .0338] | 34.1847[c] | 67.82 |
| Study Design | | | | | | |
| Cross-sectional | 1 | 38 | .0050 | [-.0160, .0259] | 66.1851[b] | 45.61 |
| Prospective/Longitudinal | -1 | 14 | -.0089 | [-.0538, .0361] | 22.9516[a] | 47.72 |
| PA Tool | | | | | | |
| Unvalidated Self-Report | -1 | 30 | .0075 | [-.0167, .0318] | 57.9738[b] | 51.70 |
| Validated Self-Report | .5 | 16 | -.0052 | [-.0370, .0266] | 23.8033 | 41.18 |
| Objective Measure | .5 | 6 | -.0376 | [-.1535, .0793] | 8.2273 | 51.38 |
| PA Definition | | | | | | |
| Volume | | 14 | -.0050 | [-.0404, .0304] | 18.7878 | 36.13 |
| General Quantity | | 5 | -.0101 | [-.0755, .0554] | 7.7320 | 61.20 |
| Quantity of Moderate to Vigorous | | 14 | -.0074 | [-.0400, .0253] | 27.8451[b] | 56.90 |
| Quantity of Mild to Moderate | | 7 | .0403[a] | [.0074, .0730] | 4.2852 | 0 |
| Frequency | | 8 | .0119 | [-.0790, .1025] | 18.2401[a] | 67.11 |
| Personality Measure Item Format | | | | | | |
| Adjective | -1 | 10 | .0029 | [-.0290, .0349] | 16.6957 | 52.08 |
| Statement/Question | 1 | 42 | .0010 | [-.0224, .0244] | 73.3707[b] | 45.48 |
| Experimental Demand | | | | | | |
| Yes | -1 | 9 | .0353 | [-.0256, .0960] | 14.4661 | 51.61 |
| No | 1 | 43 | -.0027 | [-.0223, .0168] | 72.9879[b] | 43.83 |

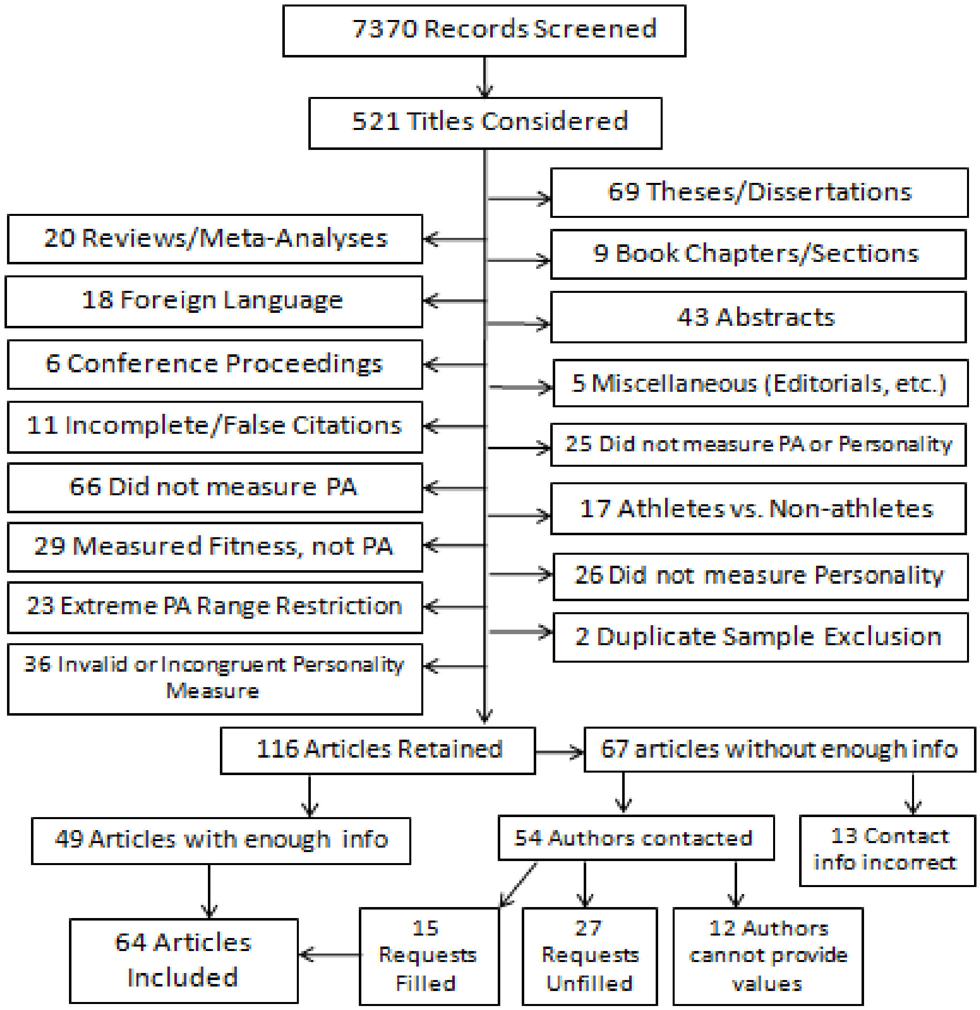


Figure 2.1.
Flow chart of study inclusion.

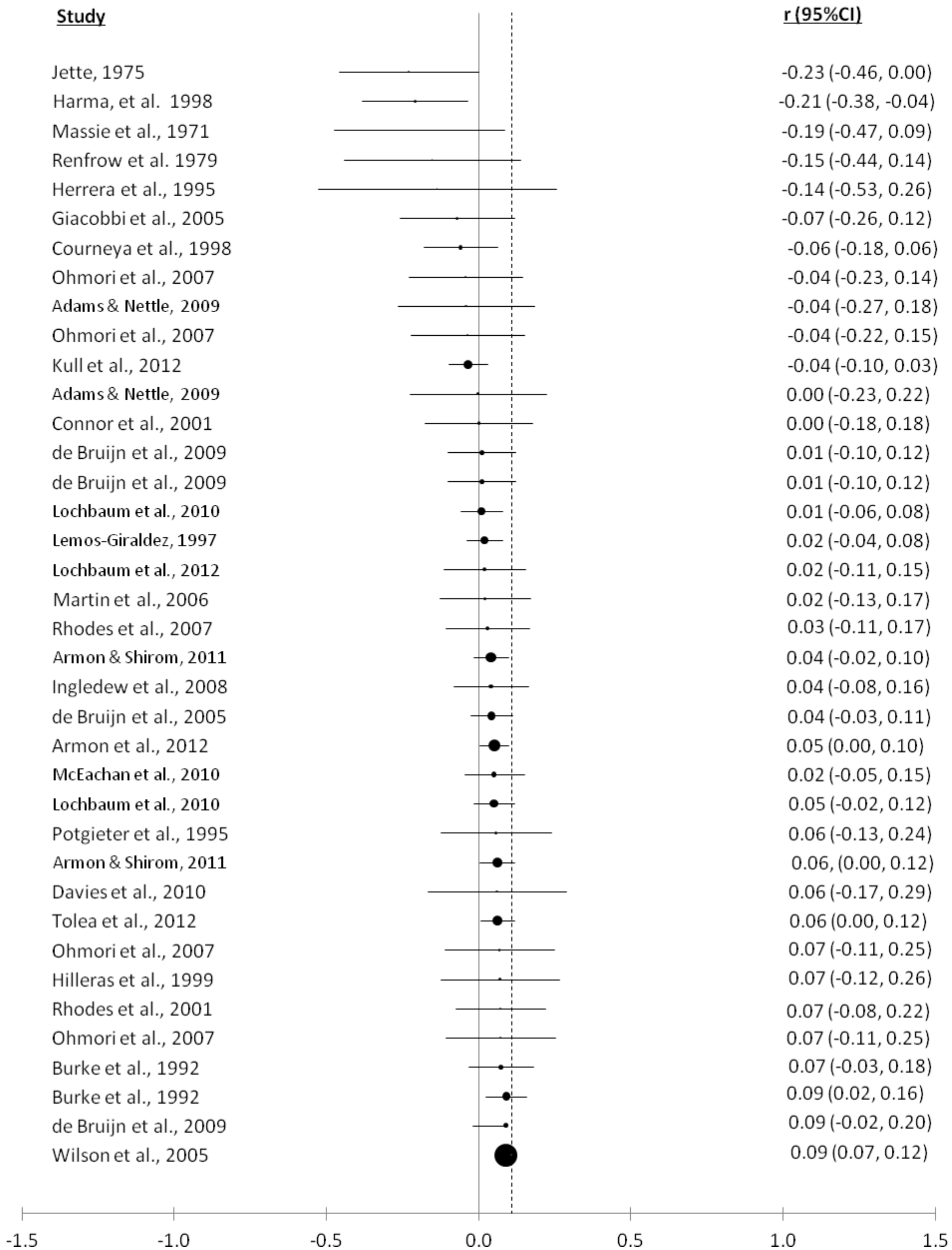


Figure 2.2.

*Forest Plot of effects for Physical Activity and Extraversion*

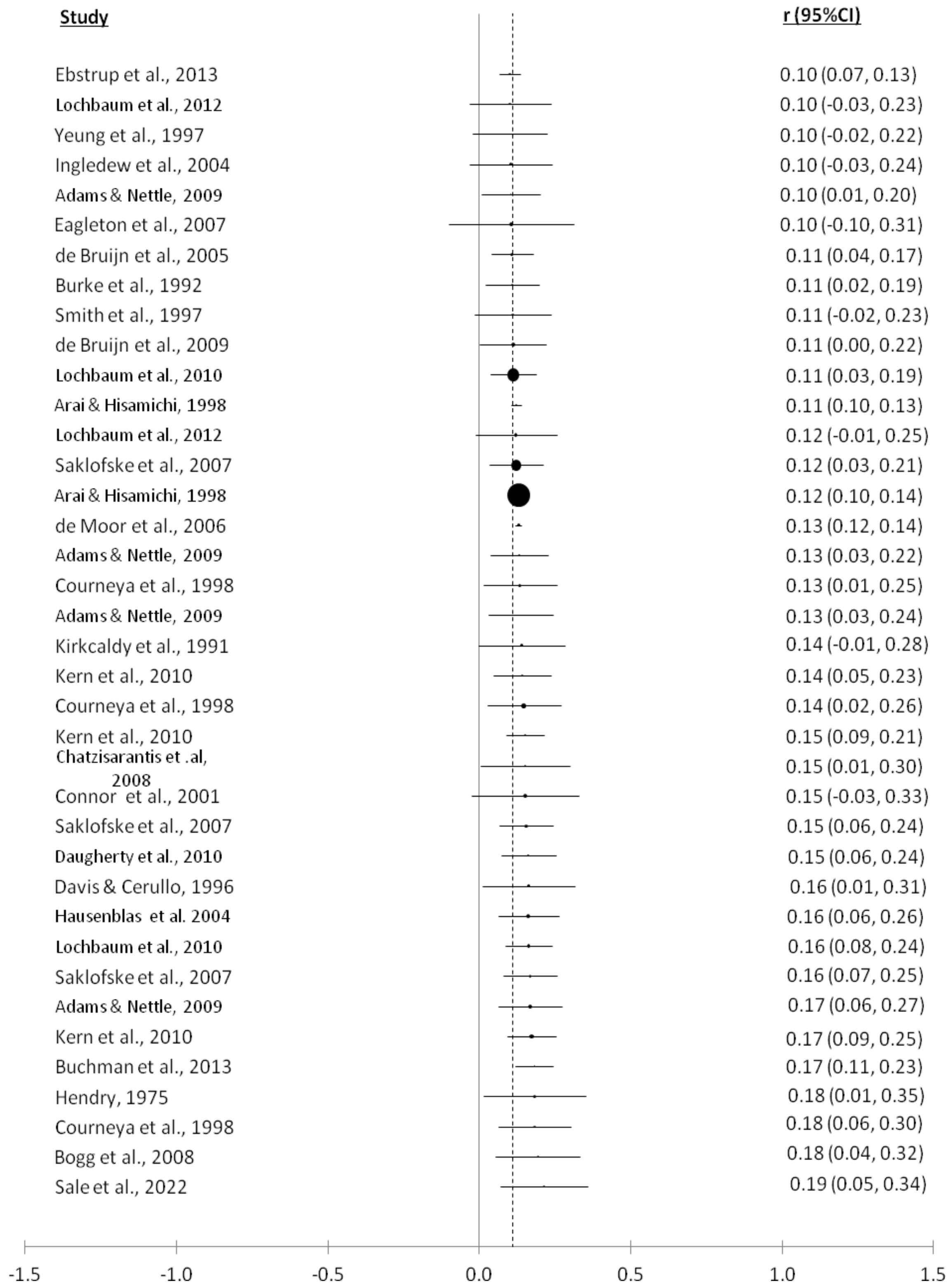


Figure 2.2. (continued)

*Forest plot of effects for Physical Activity and Extraversion*

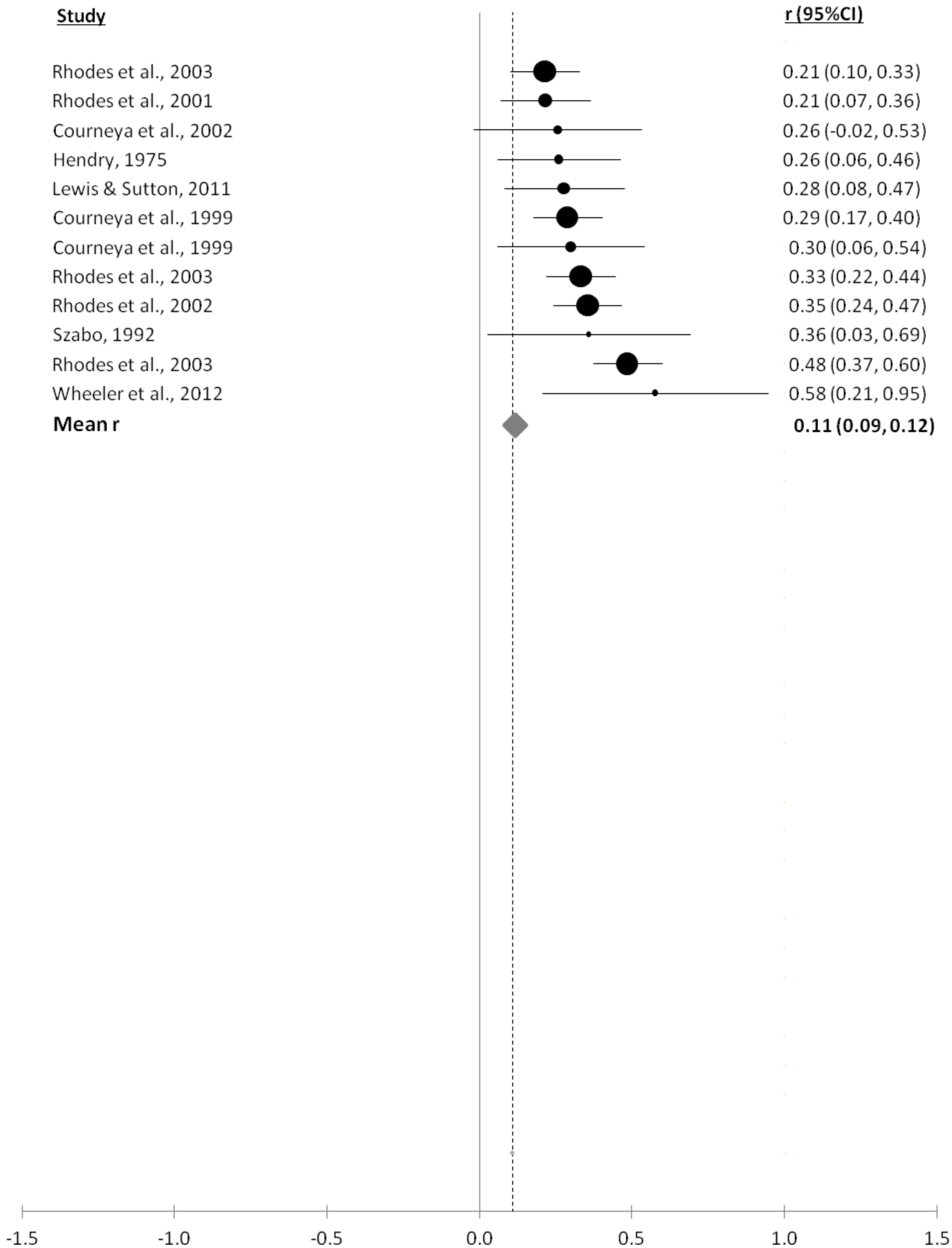


Figure 2.2. (continued)
*Forest plot of effects for Physical Activity and Extraversion*

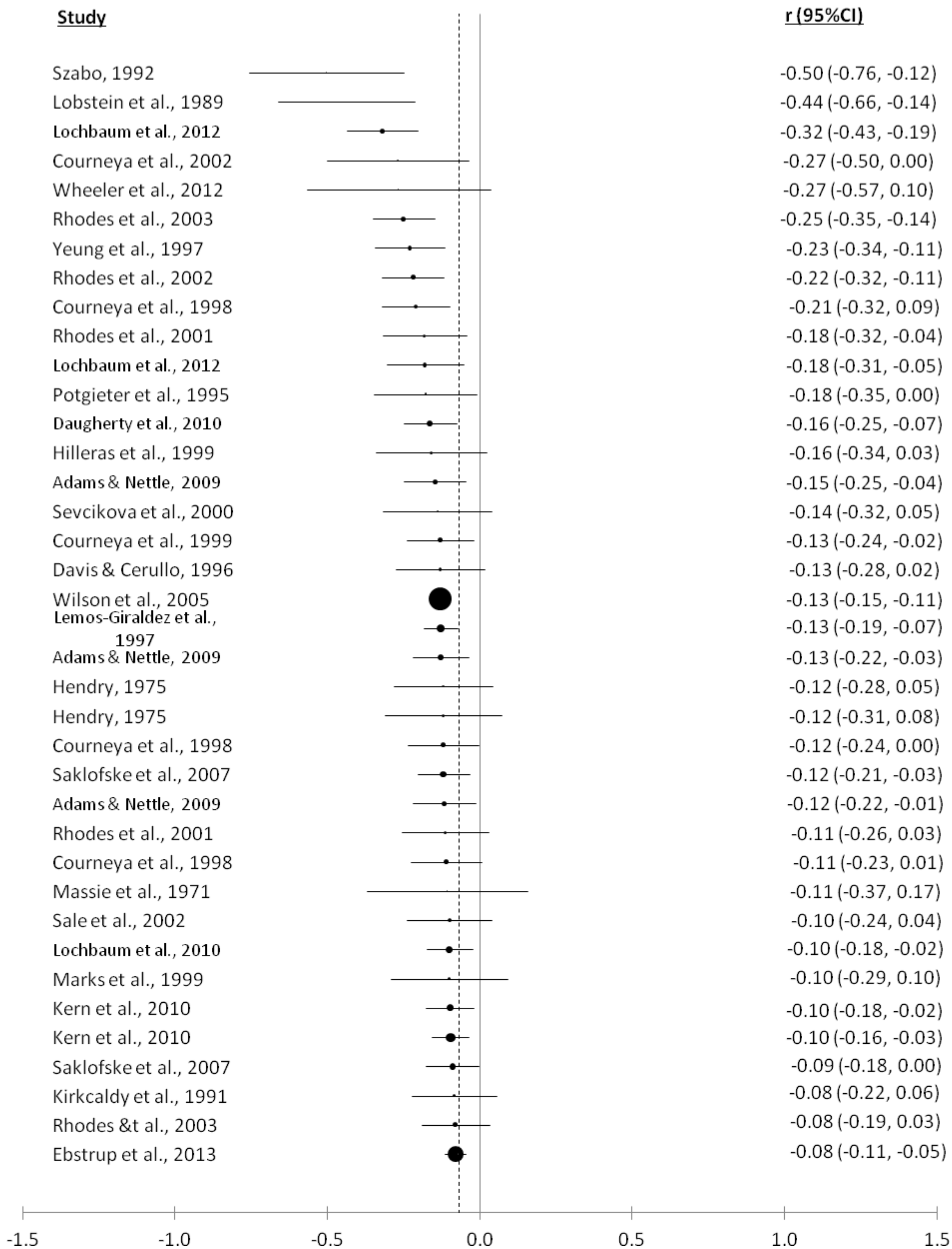


Figure 2.3.

*Forest Plot of effects for Physical Activity and Neuroticism*

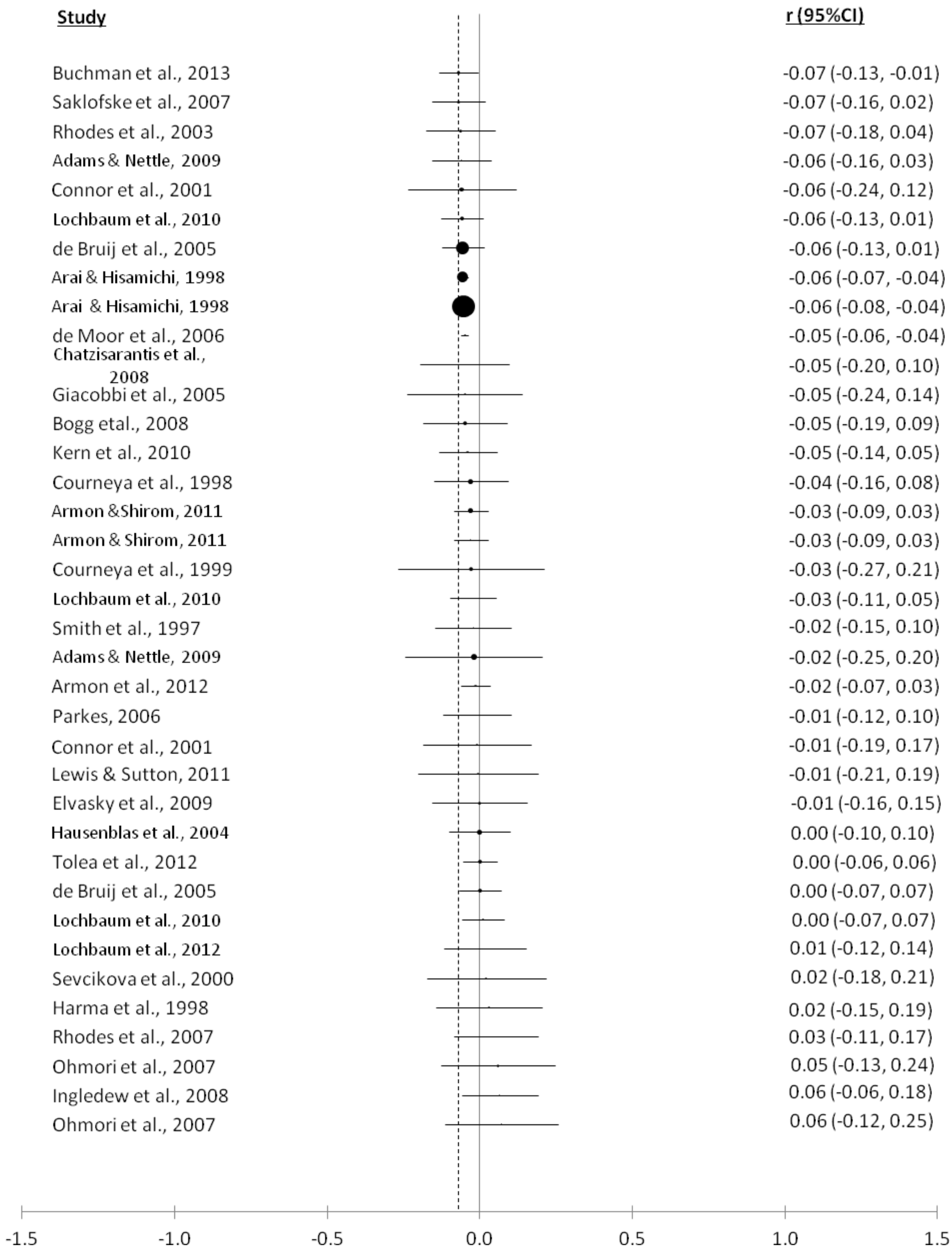


Figure 2.3. (Continued)
*Forest plot of effects for Physical Activity and Neuroticism*

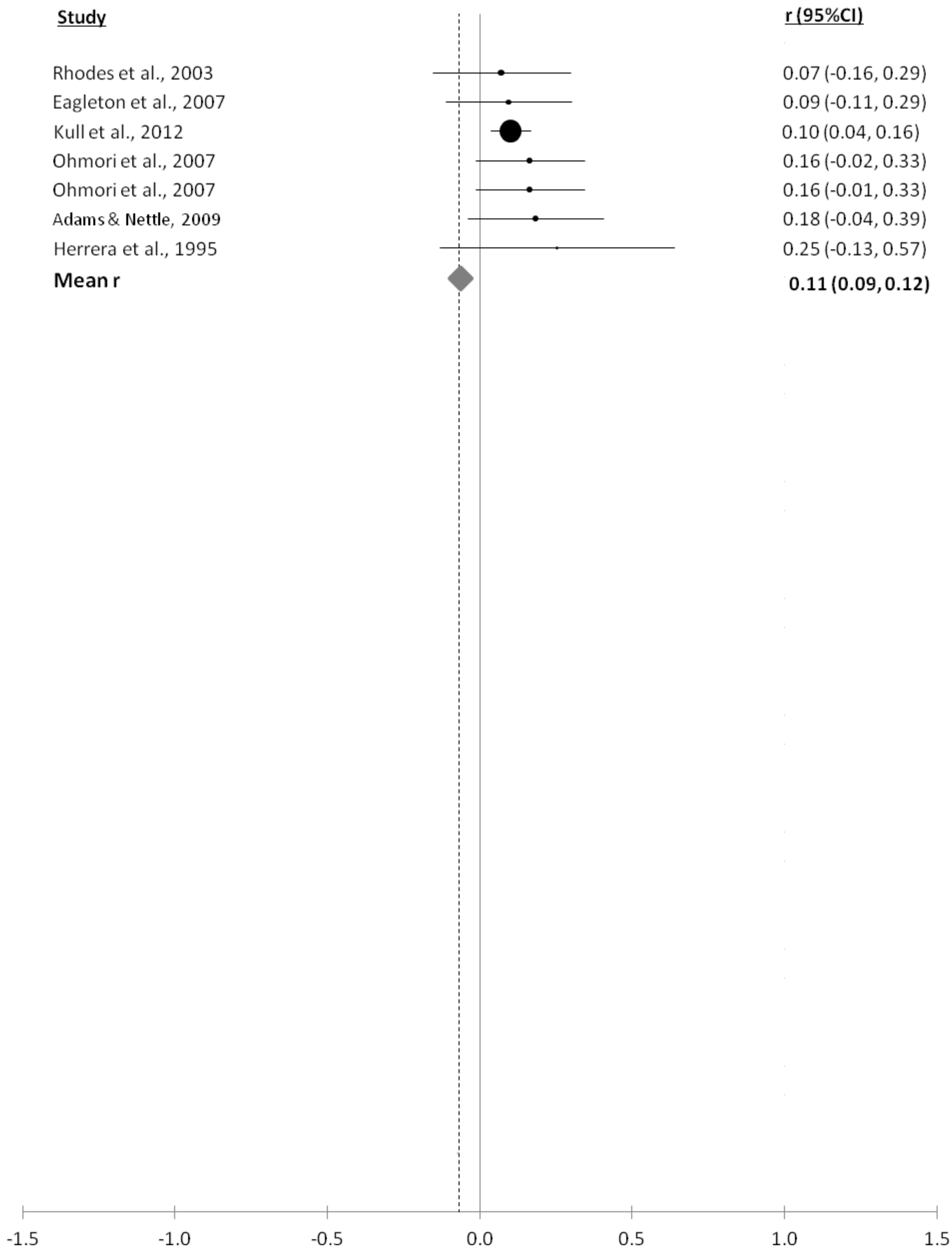


Figure 2.3. (Continued)
*Forest plot of effects for Physical Activity and Neuroticism*

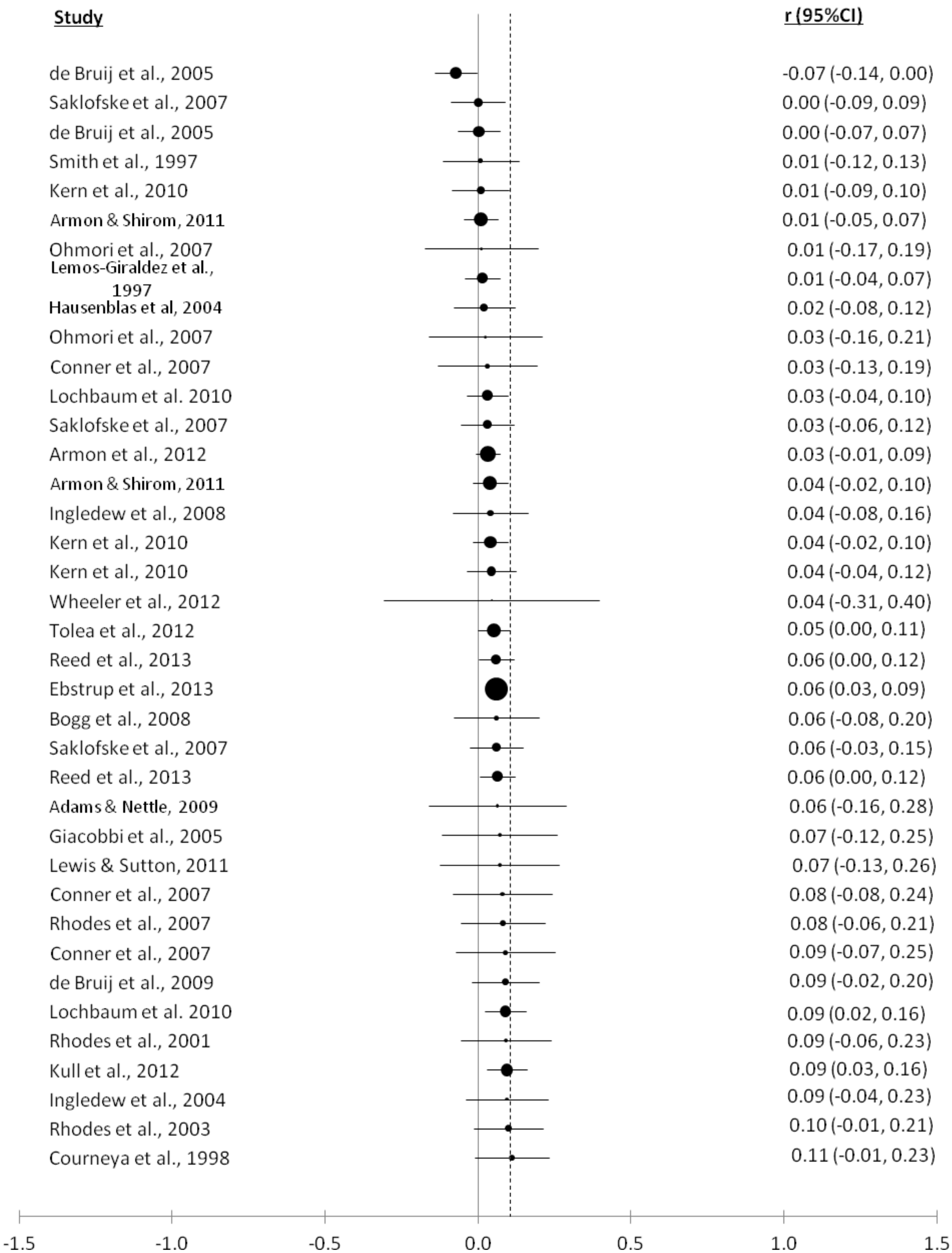


Figure 2.4.
*Forest Plot of effects for Physical Activity and Conscientiousness*

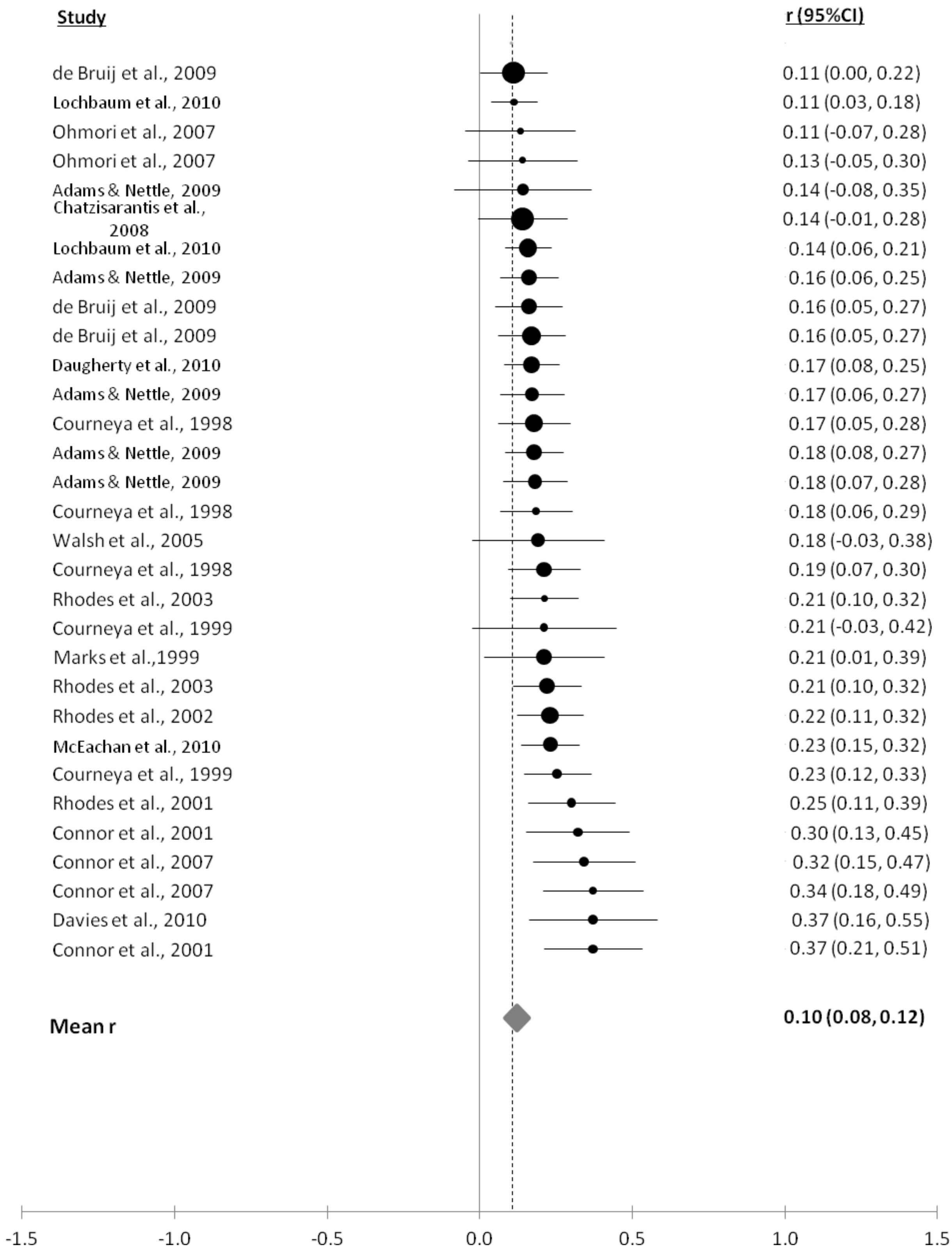


Figure 2.4. (Continued)
*Forest plot of effects for Physical Activity and Conscientiousness*

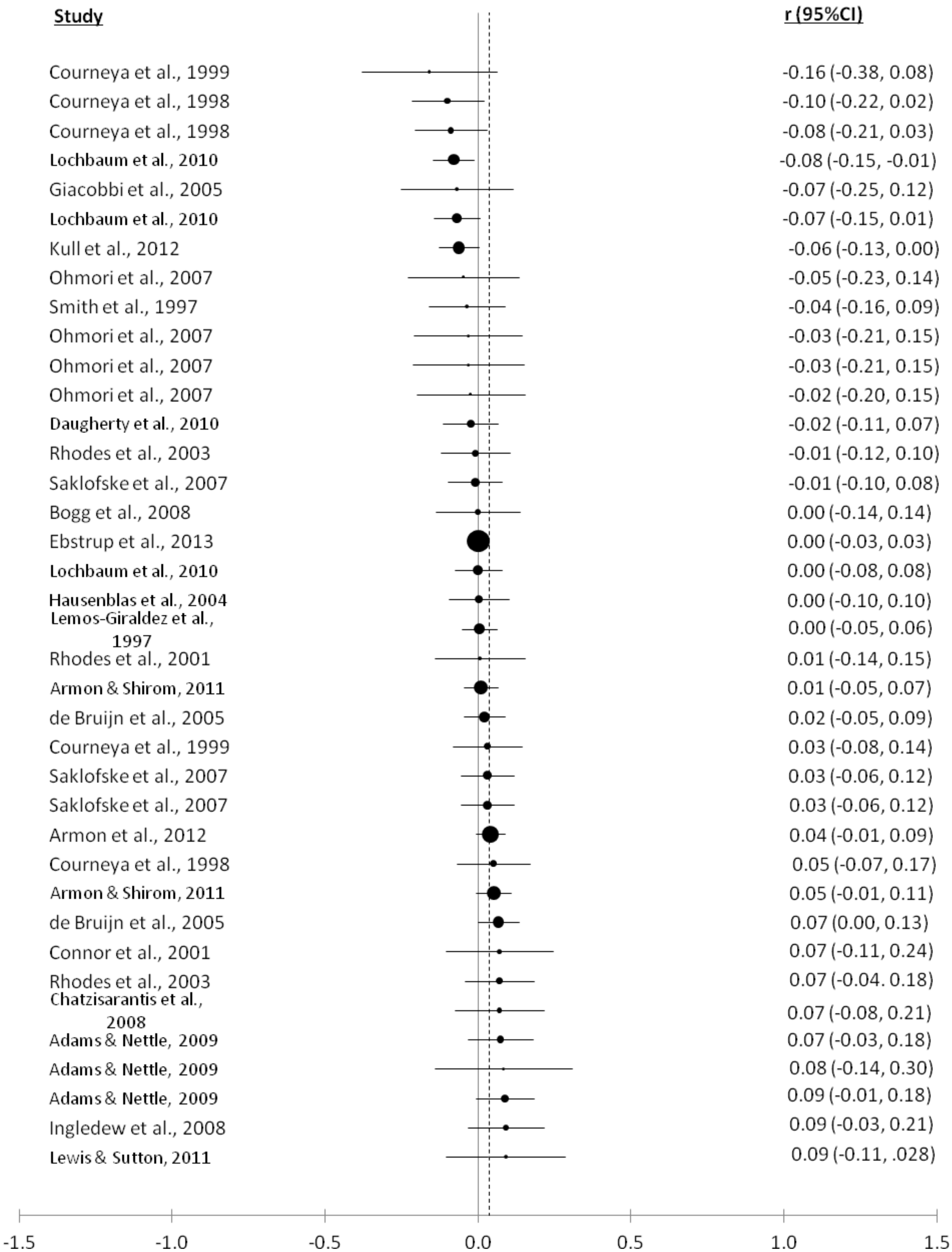


Figure 2.5.

*Forest Plot of effects for Physical Activity and Openness*

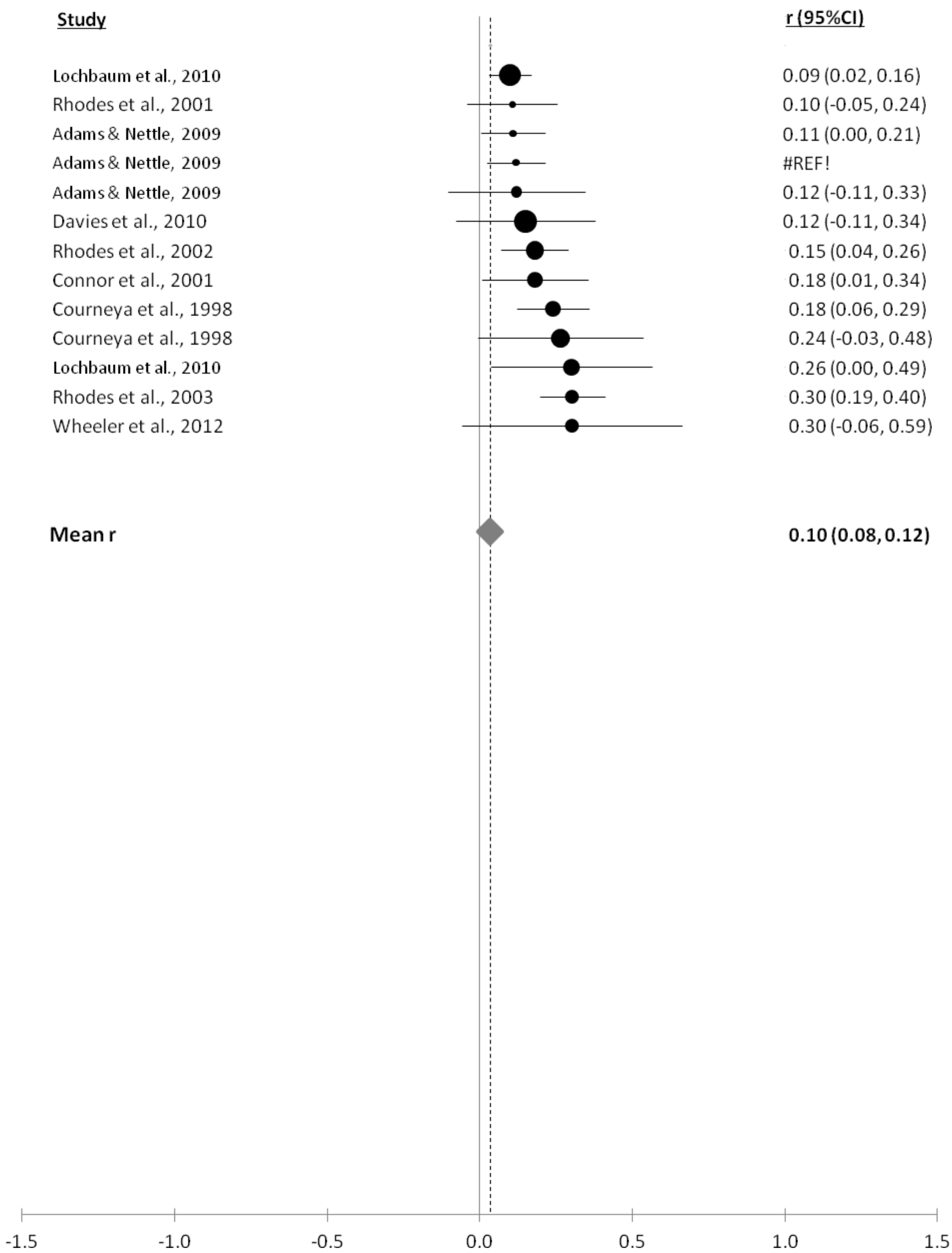


Figure 2.5. (Continued)

*Forest plot of effects for Physical Activity and Openness*

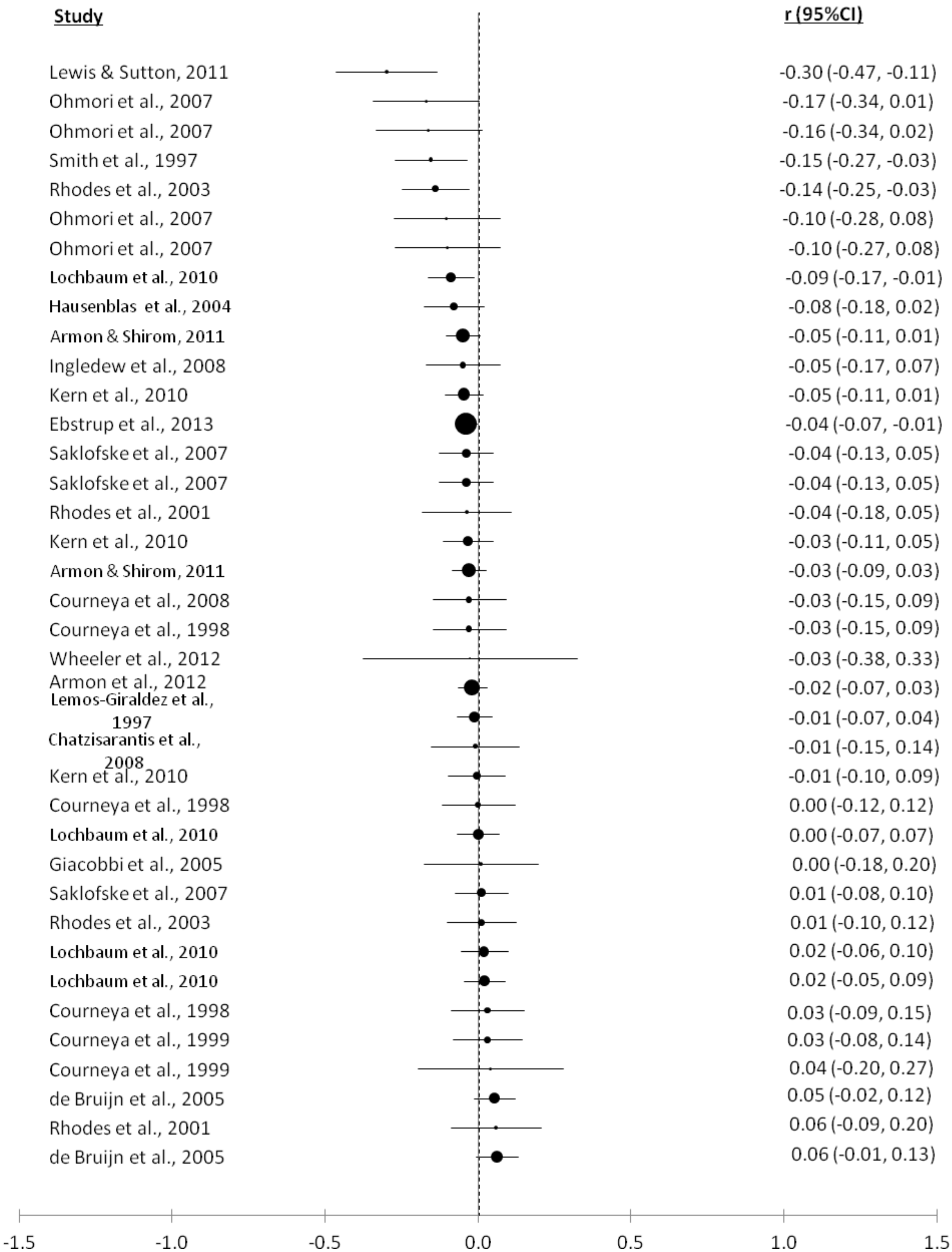


Figure 2.6.
*Forest Plot of effects for Physical Activity and Agreeableness*

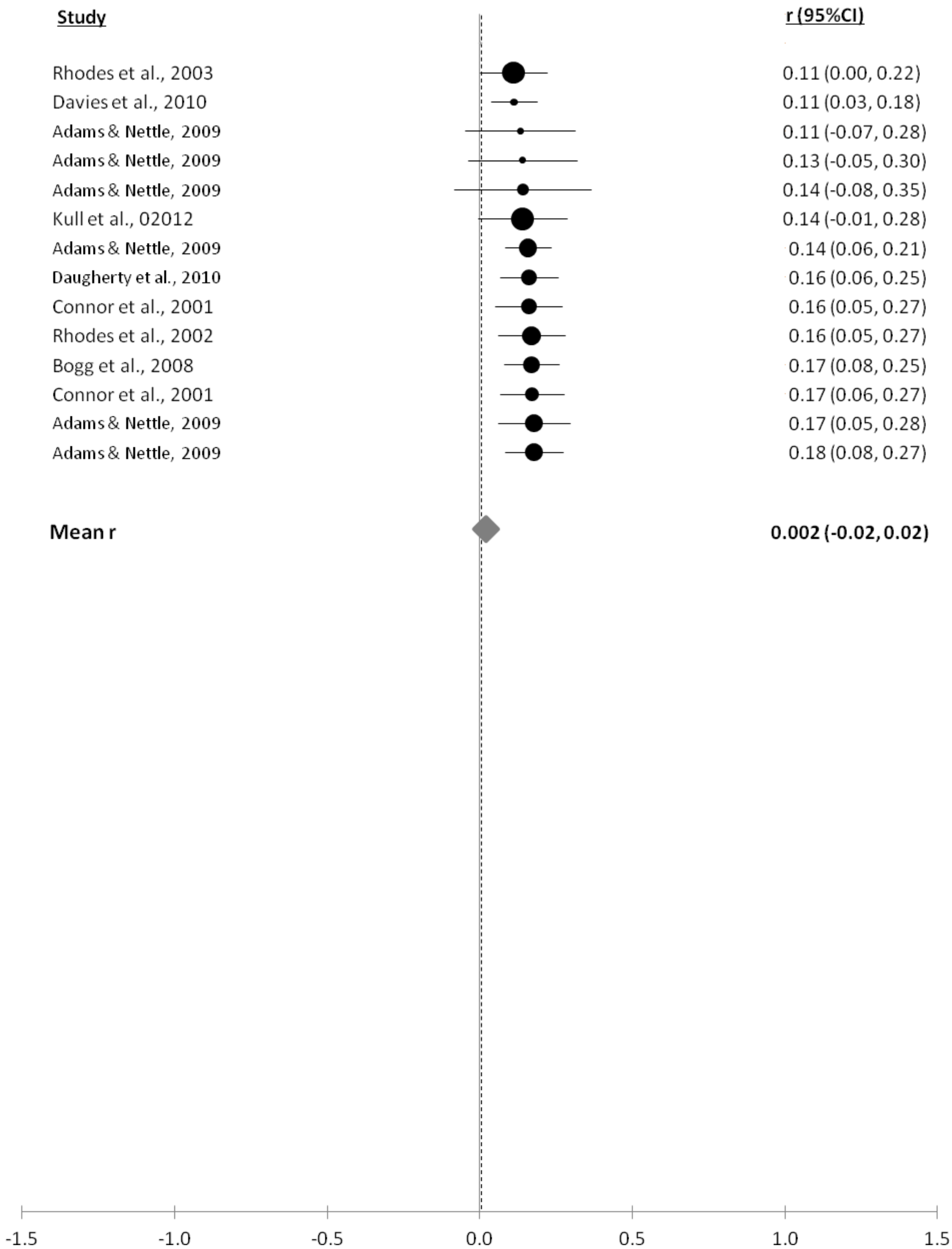


Figure 2.6. (Continued)
*Forest plot of effects for Physical Activity and Agreeableness*

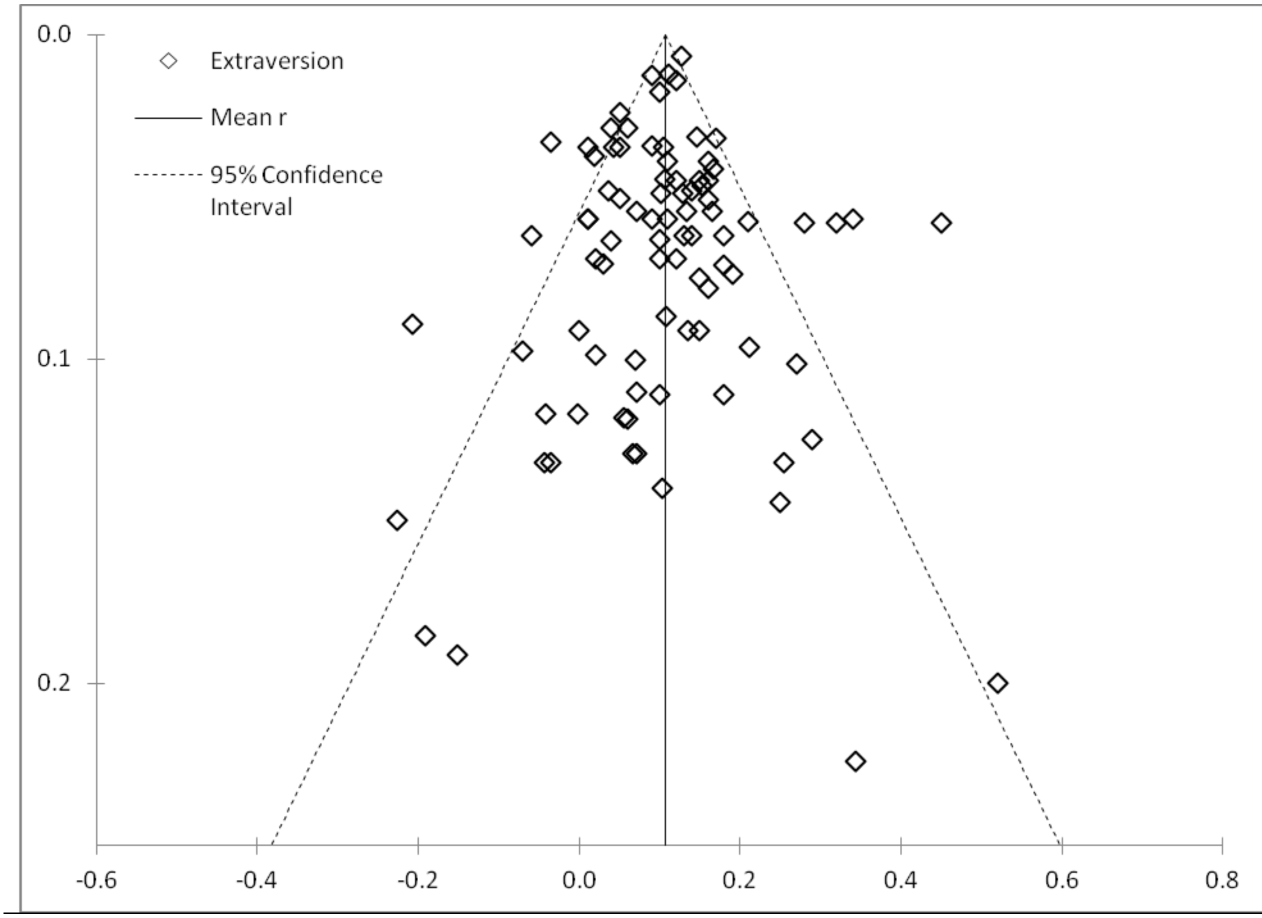


Figure 2.7.
*Funnel plot of effects for Extraversion and Physical Activity*

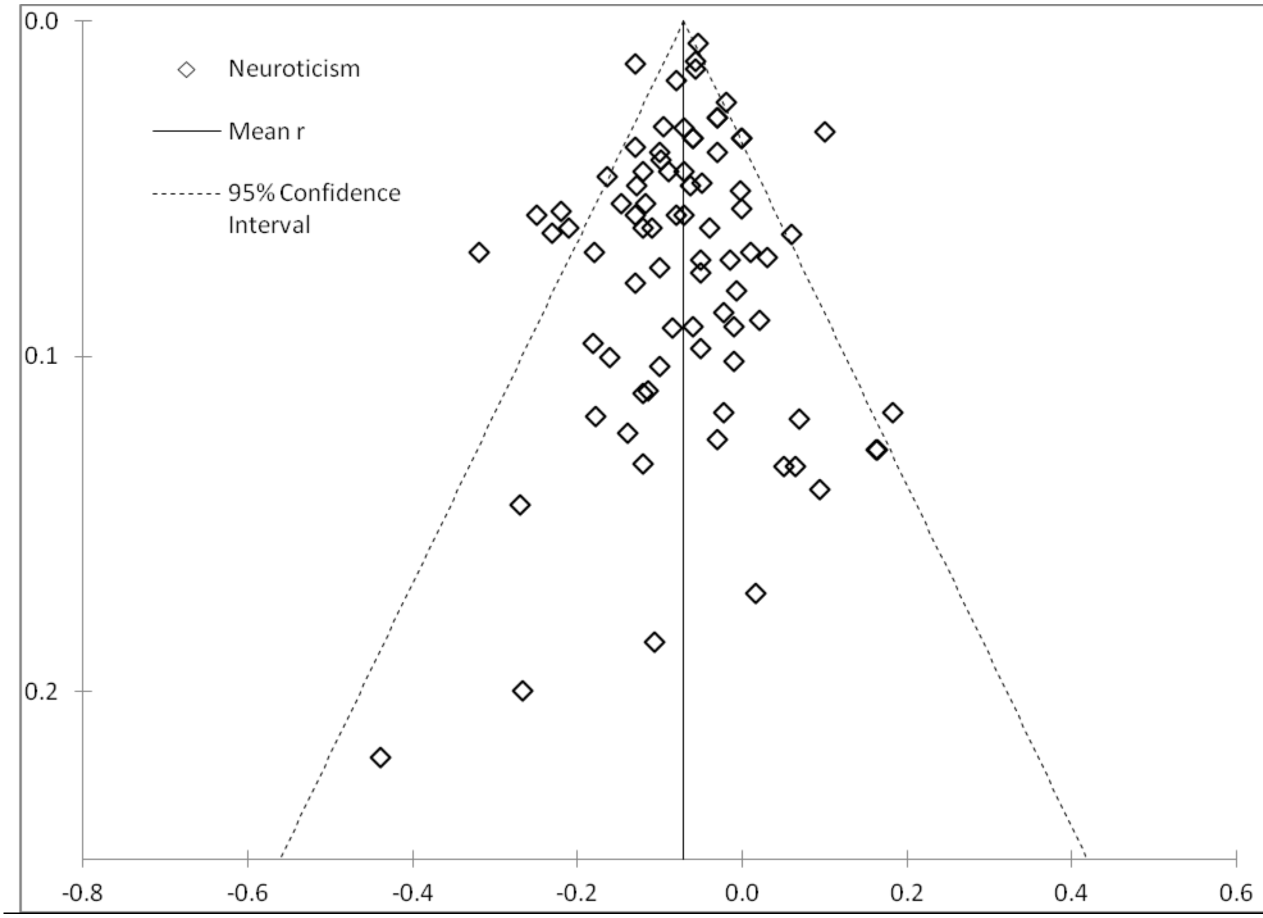


Figure 2.8.

*Funnel plot of effects for Neuroticism and Physical Activity*

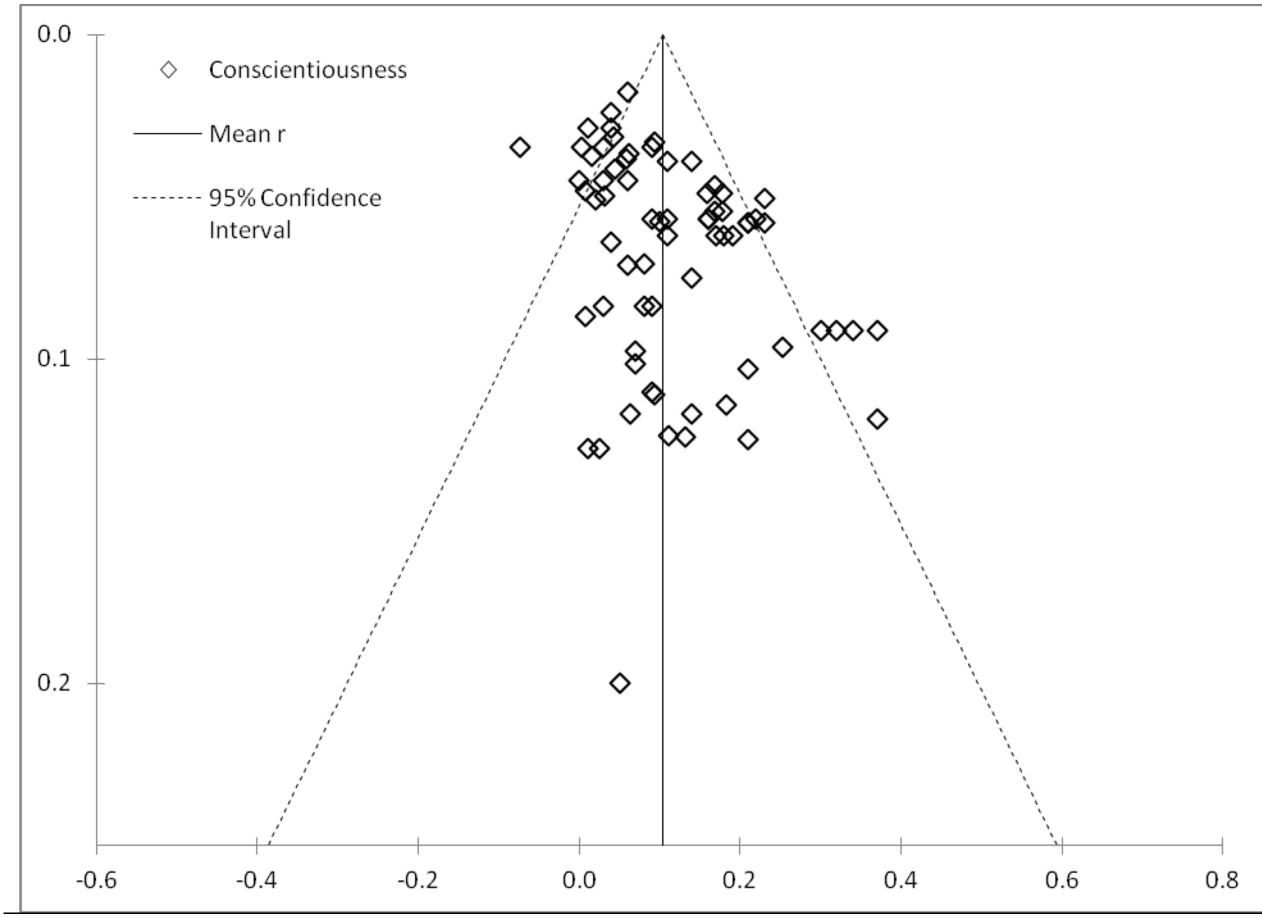


Figure 2.9.

*Funnel plot of effects for Conscientiousness and Physical Activity*

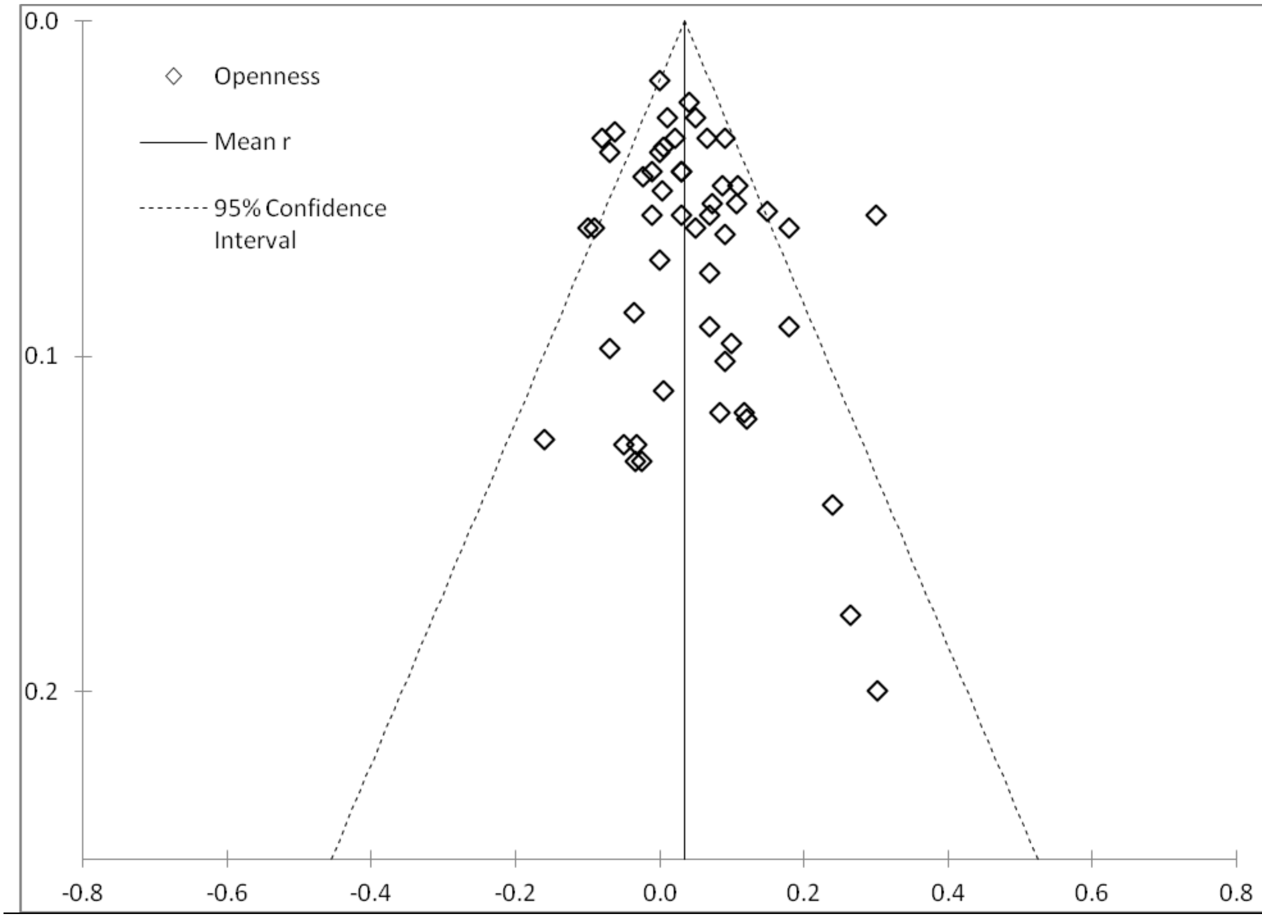


Figure 2.10.

*Funnel plot of effect for Openness and Physical Activity*

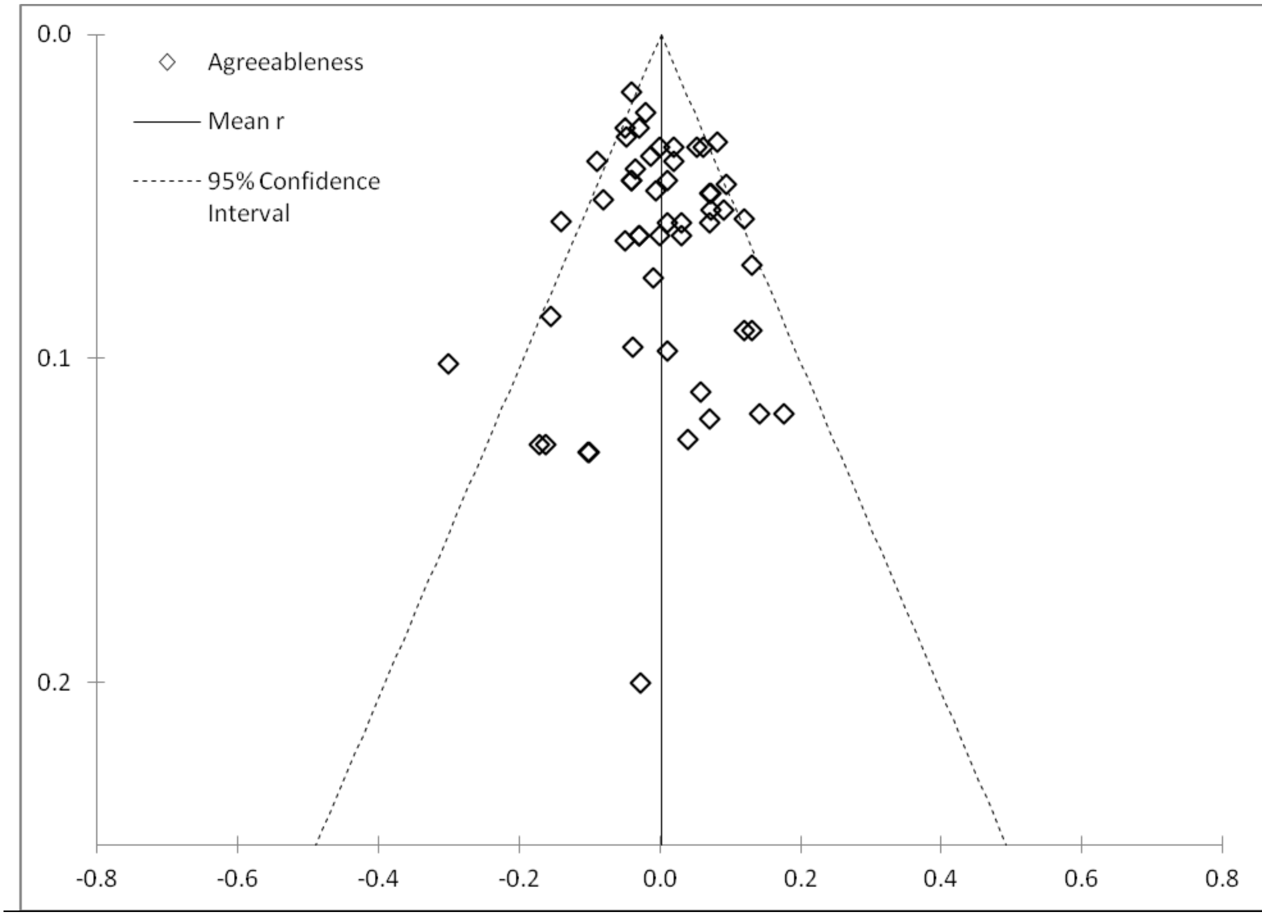


Figure 2.11.

*Funnel plot of effects for Agreeableness and Physical Activity*

CHAPTER 3

# Personality Moderates the Relationship between Physical Activity and Mental Health

Wilson, Kathryn E, Das, Bhibha M., Evans, Ellen M., and Dishman, Rodney K. To be submitted to *Personality and Individual Differences*

**Abstract**

A positive relationship between physical activity (PA) and mental health is well established, particularly for lower symptoms of depression and anxiety. However, it is unclear whether the association is direct or influenced by personality, which might moderate or otherwise explain the association. Also, past studies have not confirmed the association using an objective measure of physical activity. **Purpose:** To examine whether Extraversion (E) and Neuroticism (N) influence the association between mental health and PA measured by convergent self-reports and an accelerometer. Measures of the Behavioral Inhibition (BIS) and Behavioral Activation (BAS) systems were included as conceptual elaborations of E and N that reflect reinforcement history. **Methods:** Two samples of female undergraduates completed the personality questionnaires and 2 PA self-reports. Sample 2 also completed a third PA self-report and a measure of mental health, and wore an accelerometer for 7 days to objectively measure PA. Structural equation modeling was used to test competing models for the relationships between personality, PA, and mental health. **Results:** Measurement equivalence was confirmed for personality measures. N and BIS were independent predictors of objective PA, but not self-reported PA. BAS was related to self-reported PA. There was a suppression effect for the relationship between BIS and objective PA. E and N predicted MH. Self-reported PA was not related to MH after controlling for objectively measured PA. A 3-way interaction indicated that physical activity and mental health were unrelated in Extraverts, but positively related in Neurotic Introverts and negatively in Stable Introverts. **Conclusions:** Prediction of PA by personality depends on the method used to measure physical activity. BIS may be protective against inactivity among those reporting high N. Higher levels of physical activity were associated with better mental health only in neurotic introverts, who are at higher risk for mental health problems.

**Introduction**

A positive relationship between physical activity and several aspects of mental health is widely documented (Physical Activity Guidelines Advisory Committee, 2008). The accumulated evidence particularly supports that physical activity is associated with reduced symptoms of anxiety or depression in prospective cohort studies (e.g., Beard, Heathcote, Brooks, Earnest, & Kelly, 2007; Brown et al., 2005; Dishman, Sui, Church, Hand, Trivedi, & Blair, 2012; Jonsdottir et al., 2010; Sanchez-Villegas et al., 2008; Strawbridge et al., 2002; Wise et al., 2006) and randomized trials in patients (Asmundson et al., 2013; Herring et al., 2010; Herring et al., 2012; Mead et al., 2013; Ströhle, 2009) or healthy adults (Conn 2010; Long & Stavel, 1995). Similarly, prospective population surveys (Heesch, Burton, & Brown, 2011; Tessier et al., 2007; Wolin et al., 2007) and a randomized trial (Martin, Church, Thompson, Earnest, & Blair, 2009) of women reported that physical activity is positively associated with better mental health when it is defined more generally by a combination of symptoms of anxiety and depression. However, other evidence has suggested that the association of physical activity with anxiety or depression symptoms is not direct and might be confounded with, or otherwise explained by, personality (DeMoor et al., 2006). However, we could not find any reports of multivariate relationships among measures of personality, physical activity, and mental health outcomes. Understanding the structural relationship between personality, physical activity, and mental health would inform investigators of the neurological or genetic basis of physical activity, personality, and mental health as well as clinicians and interventionists who use physical activity or exercise as a treatment for mental health problems. Hence, the main aim of the present investigation was to describe the role of personality in the relationship between physical activity and symptoms of depression and anxiety.

Personality dimensions reflect environmental exposures and biologically based temperaments, which are present early in life and remain relatively stable across time and situations (Gonzalez, Hynd, & Martin, 1994), and they have direct and indirect influence on mental health (Diener, 2000; Steel, Schmidt, & Shultz, 2008). Generally, personality consists of individual differences in predispositions for emotions, behaviors and cognitions. Subjective well-being, as well as several of its subfacets (e.g., happiness, life satisfaction and quality of life), each are associated positively with Extraversion and negatively with Neuroticism (Steel et al., 2008), which also longitudinally predicts the development of mental disorders (Beard et al., 2007).

People scoring high on measures of Extraversion are commonly characterized as sociable, lively, active, assertive, sensation seeking, carefree, dominant, surgent and venturesome, whereas those scoring high on Neuroticism are typified as anxious, depressed, having guilt feelings, low self-esteem, tense, irrational, shy, moody and emotional (Eysenck & Eysenck, 1985; McCrae & Costa, 1999). Behavioral correlates of Extraversion and Neuroticism were elaborated by Gray (1982, 1991) and Gray and McNaughton (2000) as representing differences in the intensity of functioning of the behavioral inhibition system (BIS) and the behavioral approach system (BAS), which offer trait descriptions that are reflective of reinforcement history. Trait level functioning of the behavioral inhibition system (BIS) corresponds to trait anxiety, whereas trait level functioning of the behavioral approach system (BAS) corresponds to a propensity for behavior motivated by positive reinforcement and to accompanying positive emotions (Gray, 1991), highlighting the relevance of BIS and BAS traits to mental health. Specific hypotheses regarding the relationship between these two sets of orthogonal dimensions indicate that (1) BIS should correlate negatively with Extraversion and positively with Neuroticism, and (2) BAS should correlate positively with Extraversion and Neuroticism (Gray, 1982, 1991; Gray & McNaughton, 2000).

There is strong support in the literature for a small positive relationship between physical activity and Extraversion, and a small negative relationship between physical activity and Neuroticism (Rhodes & Smith, 2006; Wilson & Dishman, 2014). The acute behavioral outputs of BIS and BAS suggest that their respective personality traits could plausibly be related to physical activity level. Acute activation of the BIS, typically elicited by the presence of threatening or novel stimuli results in increased arousal, attention and environmental scanning accompanied by the inhibition of ongoing behavior. On the other hand, acute activation of the BAS facilitates behavioral approach toward present or anticipated appetitive stimuli. BIS-dominant individuals may accumulate less physical activity than BAS-dominant individuals because of a heightened propensity to inhibit ongoing behavior under mild to moderately threatening circumstances, whereas BAS-dominant individuals are more likely to engage in novel behaviors or sustain ongoing behavior. Despite this relevance, there is a paucity of evidence regarding BIS/BAS and physical activity behavior. Cross-sectional studies have reported a small, positive relationship between BIS and inactivity (Voigt et al., 2009) and a small, negative relationship between inactivity and Drive (a psychometric sub-factor of BAS; Carver & White, 1994) among 1014 undergraduates from four universities. Other authors have reported on the effects of BIS/BAS traits on subjective responses to acute exercise in a college-aged sample (Hall et al., 2005) and adolescents (Schneider & Graham, 2009), their relation to exercise dependence in adult men and women with unhealthy body change behaviors (Mussap, 2006, 2007), and the role of punishment sensitivity (i.e. BIS) in the personality profile of adults involved in high risk sports (Freixanet, 1991).

Population-based studies of physical activity and mental health have mainly used self-reports to measure physical activity (which may inflate their association by common-method artifact) rather than an objective measure (e.g., an accelerometer) or have not compared results using both types of measures. The relationship between personality and physical activity also might depend on physical activity measurement method (Wilson & Dishman, 2014). Evidence indicates that self-reported physical activity is more congruent with accelerometer estimates of physical activity among women than men (Dyrstad, Hansen, Holme, & Anderssen, 2014). Here, analyses were conducted to test differences in the relationship between personality and physical activity according to physical activity measurement method. We report on a test of the role of personality in the association between physical activity, measured both subjectively and objectively, and mental health, measured with two commonly used questionnaires indicating symptoms of both anxiety and depression (Hemingway, Stafford, Stansfeld, Shipley, & Marmot, 1997; Kessler, Andrews, & Colpe, 2002). We sampled young women, who have higher risk of elevated symptoms of anxiety and depression than men or older women (Alonso et al., 2004; Seedat et al., 2009). We also used confirmatory factor analysis to test the factor validity and measurement equivalence/invariance between the samples. The cross-sectional tests we report here can provide the initial evidence to encourage prospective observations or randomized trials.

The main aim of the present investigation was to describe the role of personality in the relationship between physical activity and mental health. We examined models predicting symptoms of depression and anxiety by personality and physical activity, measured by self-report and objectively by accelerometry, to test alternative hypotheses about the relationship between personality, physical activity and mental health suggested by previous population based studies using the Netherlands Twin Registry (De Moor et al., 2006; De Moor et al., 2008). It is not only plausible that personality confounds associations between physical activity and mental health, rather it might act through physical activity to impact mental health indirectly as well as directly (partial mediation), or interact with physical activity to moderate its effect on mental health.

## Methods

**Participants.** Two samples of females were recruited from the undergraduate population at the University of Georgia. Sample one (N=409) consisted of female undergraduates ages 18-25 (mean 20.3 + 1.47 years). Exclusions were made for any respondent who was male, >25 or <18 years of age, or was not a University of Georgia undergraduate. Sample two (N=298) consisted of female freshman enrolled in a USDA funded study. Inclusion criteria for that study required participants to be ages 18-20 years (mean 18.34 ± 0.49 years), campus residents, and not intercollegiate athletic participants.

**Measures.**

***Personality*.** Extraversion and Neuroticism were assessed by ten items each, selected from the International Personality Item Pool (IPIP), using a 1-5 Likert-type response format (Goldberg, 1999; Goldberg et al., 2006). BIS and BAS traits were measured with the BIS/BAS Scales (Carver & White, 1994), which are the most widely used scales for the measurement of these constructs. A single seven-item scale measured BIS trait, and three scales labeled Drive (five items), Fun Seeking (four items), and Reward Responsiveness (four items) were used to measure BAS trait. All items have a four- point ordered response format. Items are shown in supplemental Appendix A.

***Physical activity*.** Physical activity level was assessed by convergent measures: the Global Physical Activity Questionnaire (GPAQ; Armstrong & Bull, 2006) and the Godin Leisure

Time Exercise Questionnaire (GLTEQ; Godin & Shephard, 1985). In addition to these two measures, sample two completed the International Physical Activity Questionnaire (IPAQ; Booth, 2000; Craig, Marshall, Sjostrom, et al., 2003). All three self-report measures have demonstrated evidence of validity (Bull, Maslin, & Armstrong, 2009; Craig, Marshall, Sjostrom, et al., 2003; R. K. Dishman, Rooks, Thom, Motl, & Nigg, 2010; Jacobs, Ainsworth, Hartman, & Leon, 1993; Miller, Freedson, & Kline, 1994). A latent factor for self-reported physical activity was derived for samples one and two using the moderate and vigorous summary scores from the Godin LTEQ, as well as the MET/week summary score from the GPAQ. This factor was used to cross-validate the relationship between physical activity and personality between the two samples. In sample two, physical activity was estimated using the moderate-to-vigorous scores from the GPAQ, GLTEQ, and the IPAQ. In addition to completing these self-report measures, sample two participants also wore a NL-1000 piezoelectric accelerometer (McClain, Hart, Getz, & Tudor-Locke, 2010; McMinn, Rowe, Stark, & Nicol, 2010; Tudor-Locke, Bassett, Shipe, & McClain, 2011) that assessed moderate-to-vigorous physical activity for seven days. Criteria for acceptable measurement were wear times of at least 10 hours per day on at least 3 weekdays and 1 weekend day. Daily estimates of moderate to vigorous physical activity provided by the accelerometers were used to derive a latent objective physical activity factor.

***Mental health.*** General mental health was measured with the MOS 36-item Short Form Health Survey (SF-36; Hemingway et al., 1997; McHorney, Ware, & Raczek, 1993), which has been one of the most commonly used measures of mental health in physical activity studies (Physical Activity Guidelines Advisory Committee, 2008). Five items with a 6-point ordered response format make up the SF-36 Mental Health score, with higher scores indicating better overall mental health. We used the K10 to measure general mental distress (Kessler et al., 2002).

The K10 is a 10 item screening tool for which high scores indicate greater mental distress. Each measure is comprised of items that indicate symptoms of depression and anxiety. Items are shown in supplemental Appendix A.

**Procedure.** Measurement protocols were approved by the Institutional Review Board. Data collection was conducted separately for each sample. Recruitment and data collection for sample one was carried out online. Students were contacted via their UGA email address and invited to participate in the study. Interested subjects returned a completed informed consent document, and were given access to the self-report measures (SurveyMonkeyInc, 2011-2013). In addition to the survey hyperlinks, participants were emailed instructions to complete only one or two surveys at a time in the order of their preference. They were told to complete the measures within the following 7 days. On the 7$^{th}$ day, reminder emails were sent to participants who were missing data, and they were allotted an additional 48 hours to complete the remaining surveys.

Data collection for sample two included two laboratory visits, 8 days apart, as well as online survey completion. After submitting informed consent, participants visited the laboratory for accelerometer assignment and instruction, as well as instructions for the online surveys. Participants were shown how to properly wear the accelerometer on their waistband and asked to wear it during all waking hours of the following 7 days, except during activities involving water, such as showering or swimming. Sample two was given the same instructions for survey completion as was sample one. On the morning of the 7th day, reminder emails were sent to participants to complete any unfinished surveys before they returned the following day to return their accelerometers

**Statistical analysis.** Full information robust maximum likelihood estimation was used in Mplus 7.11 (Muthén & Muthén, 2007). Critical z-scores (parameter estimate/SE) were used to test significance of relations (fully standardized β coefficients) between variables ($p < .05$). There was <3.0% missing data for sample one (723 of 24,660 questionnaire responses), and <1% missing self-report data (369 of 39,336 questionnaire responses) and <4% missing accelerometer data (79 of 2086 data entries) for sample two.

***Model fit***. The chi-square ($\chi^2$) statistic, comparative fit index (CFI), root mean square error of approximation (RMSEA) and its 90% confidence interval, Tucker-Lewis index (TLI) and standardized root mean square residual (SRMR) were used to evaluate model fit (Bollen, 1989; Hu & Bentler, 1999). Values of CFI ≥ 0.90 were judged to be acceptable, while values > 0.95 indicated good fit. Values of the RMSEA ≤ 0.06 and ≤ 0.08 indicated close and acceptable fit. Values of TLI ≥ 0.90 were interpreted as indicating acceptable model fit. Concurrent values ≥0.95 for CFI and ≤0.08 for SRMR provide optimal protection against type I and type II error rates (Hu & Bentler, 1999). Models including interaction terms to test for moderation were compared using the Bayesian Information Criterion (BIC) (Bollen, Harden, Surijat, & Zavisca, 2014).

***Confirmatory factor analyses***. The factor validity of each personality measure was examined in sample one by confirmatory factor analysis (CFA). Two primary factors were hypothesized for the BIS/BAS scales; one latent factor for BIS and a second order BAS factor comprised of three first order factors; Drive, Fun Seeking and Reward Responsiveness (Carver & White, 1994) A two factor model was hypothesized for the measures of Extraversion and Neuroticism (Eysenck, 1970). From sample two, a single factor was hypothesized for mental health measured by the SF-36, and a separate factor was specified mental distress measured by the K10. If a hypothesized model was not supported, modification indices, standardized residuals, squared multiple correlations, and covariances between items were examined to determine if misfit was the result of a problem item or the hypothesized factor (Anderson & Gerbing, 1988). Problem items were trimmed from each model until the model demonstrated acceptable fit. Trimmed measurement models for personality were then specified for sample two. The composite reliability index (CRI) was used to estimate the internal consistency of each latent factor (Raykov, 1997).

***Measurement equivalence/invariance.*** Assessment of measurement invariance of personality constructs across samples began with an omnibus test of equal covariances between groups. Had equivalence of covariance matrices not been supported, tests of increasingly restrictive levels of equivalence would have proceeded to identify the highest level of measurement invariance reflected in these data, as recommended by Vandenberg & Lance (2000).

***Structural model equivalence.*** Equivalence of structural parameters for the relationships between personality factors and self-reported physical activity between groups was tested using the Wald statistic (Wald, 1943). First, all structural parameters were specified as equal, and the equivalence of the entire model was tested. In the case of a significant W ($p < .05$), structural parameters were tested for invariance individually to identify the source(s) of significant difference in the structural model between samples. Structural parameters found to be significantly different between samples were excluded from subsequent model specifications.

***Structural model for physical activity measurement.*** The cross-validated structural model was retained for further analysis within sample two. The structural model was expanded to test the hypothesis that the relationship between personality and physical activity is dependent on physical activity measurement. Parameters were specified to test the direct effects of personality factors on correlated physical activity factors representing moderate to vigorous physical activity measured by self-report or by accelerometry.

***Structural models for mental health.*** In an effort to minimize the complexity of the final model, we restricted models examining the impact of personality on the relationship between physical activity and mental health to include only personality factors that were independent predictors of mental health. Analyses were therefore guided by a preliminary model examining multivariate prediction of mental health by all four personality factors.

The hypothesis that the relationship between physical activity and mental health is confounded with personality was tested through a sequence of models testing first for evidence of confounding, then of mediation, and finally for moderation. Models were tested separately for each physical activity factor. The model representing a confounding effect of personality was specified to reflect (M1) exogenous factors of personality and physical activity unrelated to each other, and their direct effects on mental health. Confounding was further tested in a model specifying partial mediation of personality effects on mental health through physical activity (M2). Support for confounding would be indicated by non-significant direct effects of physical activity on mental health in both models, and the absence of any indirect effects from personality through physical activity to mental health in M2. Full mediation was tested such that personality was specified to act through physical activity to effect mental health indirectly (M3). Finally, to test the hypothesis that personality may moderate the effect of physical activity on mental health, we first specified a moderating effect for the personality factor observed to have the strongest relationship with mental health (M4), then for other included personality factors (M5-M*k*). Moderation is supported in the presence of a significant 2-way interaction between a personality factor and physical activity. In this case, we tested the possibility of more complex interactions by specifying additional personality factors contributing to the interaction term. Significant interactions were decomposed using standard procedures (Aiken & West, 1991; Jaccard & Wan, 1995). Decomposed interactions were standardized to a t-distribution for graphical representation.

## Results

**Confirmatory factor analyses.** Model fit statistics for the confirmatory factor analyses are displayed in Table 3.1. Mental distress as indicated by the K10 was extremely non-normal, as indicated by the values for skewness (14.6784) and kurtosis (215.845), and it was highly correlated with the SF36 Mental Health Scale before (r = -.971) and after (r = -.978) square root transformation. Hence, it was excluded from further analysis. Confirmatory factor analyses of the personality scales in sample one, and the SF36 Mental Health Scale in sample two demonstrated poor fit. Modification indices specified collinearity or cross-loading of several items for the included scales, and a total of 7 items from the IPIP (items 10, 12 and 14 from Extraversion; items 5, 7, 9 and 15 from Neuroticism) and 4 items from the BIS/BAS scales (items 2, 19 and 22 from BIS, and item 21 from the Drive subscale of BAS) were trimmed to obtain acceptable fit. The trimmed measurement models for both personality measures had acceptable fit in sample two. Acceptable fit for the SF-36 Mental Health Scale in sample two was achieved by the removal of item 9d, as modification indices suggested it was collinear with other scale items. Measurement models for the latent variable representing self-report physical activity were identified by only three indicators (i.e., saturated, df = 0), so model fit could not be tested. In both samples, factor loadings were not significant ($p$>.05) for indicators of the latent self-report physical activity factor intended to be used for cross-validation, and internal consistency was low (CRI = .477 in sample one, and .386 in sample two). Expansion of this factor to include the combined moderate and vigorous scores from the Godin as well as the moderate to vigorous physical activity score from the IPAQ from sample two resulted in factor loadings >.620 ($p$<.001) for all indicators, and improved internal consistency (CRI = .610). The measurement model for objective physical activity within sample two had acceptable fit. Full and trimmed measurement models for the psychometric measures used are illustrated in supplemental Appendix B.

**Measurement equivalence/invariance.** Equivalence of the covariance matrices between samples for the Extraversion and Neuroticism scales was supported ($\chi^2(91) = 119.446$, CFI = 0.990, TLI = 0.983, RMSEA = 0.030 (0.011, 0.044), SRMR = 0.051) as was that for the BIS/BAS scales ($\chi^2(136) = 145.993$, CFI = 0.995, TLI = 0.992, RMSEA = 0.014 (<0.001, 0.030), SRMR = 0.082). Poor internal consistency and poorly performing indicators for the self-report physical activity factor intended for use in cross-validation resulted in its exclusion from the estimation of measurement and structural invariance between samples.

**Bivariate correlations between latent factors.** Bivariate relationships between the latent variables measured for comparison between samples, and for the models examining physical activity measurement and mental health outcome within sample two are listed in Table 3.2. Correlations between personality factors were significant, except for between BIS and BAS, and BAS and Neuroticism. In sample two, self-report physical activity was significantly correlated with Extraversion, BAS, and objective physical activity, which was also significantly correlated with Neuroticism. All factors except for BAS were significantly correlated with mental health.

**Structural equivalence/invariance.** Structural parameters representing associations between personality factors for each sample, and Wald statistics comparing parameters between samples, are listed in Table 3.3. Model fit was marginal in both samples (Sample one: $\chi^2$ (368) = 772.909, CFI = 0.882, TLI = 0.869, RMSEA = 0.052 (0.047, 0.057), SRMR = 0.066; Sample two: $\chi^2$ (368)=611.655, CFI = 0.893, TLI = 0.882, RMSEA = 0.047 (0.041, 0.054), SRMR = 0.068). Neuroticism was significantly correlated with BIS and Extraversion, which was also significantly correlated with BAS within both samples. A significant correlation between BIS and Extraversion was only observed in sample one. Wald statistics confirmed that the only significant structural difference between samples was the correlation between BIS and BAS. This relationship did not reach significance in either sample.

**Structural model for physical activity measurement.** The structural model testing differential prediction of physical activity by personality according to physical activity measurement method ($\chi^2$ (df) = 990.275 (684); RMSEA (90% CI) = 0.039 (0.033, 0.044); CFI = 0.900; TLI = 0.892; SRMR = 0.062) is illustrated in Figure 3.1. Self-reported physical activity was independently predicted by BAS, whereas Neuroticism and BIS were observed to independently predict objective physical activity. This observation highlighted a suppression effect for the relationship between BIS factor and objective physical activity resulting from an interaction between BIS and Neuroticism. Decomposition of the interaction is illustrated in Figure 3.2 as estimated scores for objective physical activity among individuals $\pm$1 standard error from the mean of each factor (BIS and Neuroticism) standardized to a t-distribution.

**Structural models for mental health.** In the preliminary model predicting mental health by personality, Extraversion ($\beta$ = 0.219, SE = 0.086) and Neuroticism ($\beta$ = -0.581, SE = 0.128) were both independent predictors of mental health ($\chi^2$ (df) = 879.896 (482); RMSEA

(90% CI) = 0.053 (0.047, 0.058); CFI = 0.860; TLI = 0.846; SRMR = 0.072). The observed significant bivariate relationship between BIS and mental health was accounted for by Neuroticism in the multivariate model. Fit statistics for the models testing the influence of Extraversion and Neuroticism on the relationship between physical activity and mental health for each physical activity factor are displayed in Table 3.4.

Models for self-report physical activity support a confounding effect of personality on the relationship between physical activity and mental health. In the models testing confounding and partial mediation (M1 and M2, respectively), inclusion of Extraversion and Neuroticism in the model reduced the direct effect of physical activity on mental health to a non-significant value ($p<.05$). The model testing full mediation (M3) failed to support significant indirect effects of personality through self-report physical activity on mental health. Interactions between personality and self-report physical activity in the moderation models (M4 and M5) were not supported. The model for partial mediation (M2) had better fit than competing models. Figure 3.3 illustrates the partial mediation model (M2) reflecting a confounding influence of personality on the relationship between self-report physical activity and mental health.

Significant moderation in the form of a 3-way interaction (M6) between physical activity, Neuroticism and Extraversion ($p = .015$) was observed as the best fitting model of those testing the relationship between objective physical activity, personality and mental health. The structural model is illustrated in Figure 3.4. Decomposition of this 3-way interaction is illustrated in Figure 3.5 as estimated scores for SF-36 mental health score among individuals $\pm$1 standard error from the mean of each factor (Neuroticism, Extraversion, and objective physical activity) standardized to a t-distribution. The plot indicates that mental health and physical activity are unrelated among extraverts, positively related among neurotic introverts, and negatively related among stable introverts.

**Discussion**

We present initial evidence describing the relationship between personality, physical activity and a measure of mental health in a multivariate structural model using both subjective and objective measurements of physical activity. The primary finding of this study is that the relationship between physical activity and mental health is dependent on personality. Extraversion and Neuroticism confound the relationship between self-reported physical activity and mental health, as measured by the SF-36. In contrast, objectively measured physical activity interacts with personality to influence mental health, indicating a moderated relationship. These results extend previous findings that suggested the bivariate associations of self-reported physical activity with symptoms of anxiety or depression might be explained by Extraversion or Neuroticism (De Moor et al., 2006). Strong evidence is provided for these observations through extensive preliminary analyses supporting the validity of measurement and structural models for the personality and physical activity constructs, and their interrelationships, as well as the inclusion of objective measures of physical activity. The use of convergent measures for self-report physical activity allowed for the estimation of a latent self-report physical activity factor covering a broader range of behavior than is typically captured in studies using self-reports of physical activity. Also, to our knowledge, we report the first evidence for the relationship between BIS and BAS traits and objectively measured physical activity, concurrent with measures of Extraversion and Neuroticism as correlates of physical activity level.

We confirmed the measurement equivalence/invariance of the scales used to assess personality in the two samples (Vandenberg & Lance, 2000). The model for structural equivalence of correlations between the four personality factors partially supported the theoretical relationship between the constructs (Gray, 1982, 1991; Gray & McNaughton, 2000). As expected, BIS was negatively correlated with Extraversion and positively with Neuroticism, and BAS was positively associated with Extraversion. Also, BIS and BAS were orthogonal, consistent with theory. Conversely, the lack of a significant correlation between BAS and Neuroticism, and a negative correlation between Extraversion and Neuroticism disagree with theoretical assumptions (Eysenck, 1970; Gray, 1991), but are consistent with other literature reporting a small to moderate negative relationship between Extraversion and Neuroticism (e.g. Ohmori et al., 2007; Steel et al., 2008). There is a lack of consensus on how best to measure the BAS construct (Torrubia, Avila, & Caseras, 2008), which is less well elaborated in Gray's writings than is BIS. Nonetheless, the observed structural relationship between these constructs generally supports their theoretical associations.

Next, the cross-validated model for the relationships between personality factors was extended to test the expected differences in the relationship between physical activity and personality according to physical activity measurement method. We confirmed that traits did not uniformly predict physical activity measured by self-report or by accelerometer, nor did the traits correlate as strongly with objectively measured physical activity as with self-report physical activity, raising suspicion of a common-method artifact (e.g., socially desirable responding to self-report measures of physical activity). This finding is corroborated by the cumulative evidence from other studies showing that the relationship between Neuroticism and physical activity among female samples depends on the type of measure used to assess physical activity (Wilson & Dishman, 2014). Replications studies are encouraged to include a lie scale to test this possibility.

Extraversion and BAS each had significant bivariate correlations with self-reported physical activity, but the relationship with Extraversion was accounted for by its shared variance with BAS in the multivariate model. This was surprising because of the strong support for a significant positive relationship between Extraversion and physical activity in the literature (Rhodes & Smith, 2006; Wilson & Dishman, 2014). More work will be necessary to clarify this effect. There is evidence that self-reported physical activity is susceptible to social desirability response bias among female undergraduates (Motl, McAuley, & DiStefano, 2005), though the role of Extraversion and/or BAS has not yet been considered in relation to this observation. It is plausible that individuals with high intensity BAS functioning respond in a socially desirable way to self-report physical activity measures resulting from anticipation of positive feedback, or a desire to be viewed in a more positive light by others, and that support for the relationship between Extraversion and physical activity is confounded by their strong individual relationships with BAS. Because we were unable to include a factor for self-reported physical activity in the structural equivalence model, and in light of the limited amount of evidence for physical activity level and BIS/BAS, it is unclear whether the strength of this relationship between BAS and self-reported physical activity is dependent on sample characteristics. It seems reasonable that a sample of female freshman would place high importance on their personal image, and increments in BAS would predispose them for socially desirable responding, especially to items regarding health practices or body image.

Neuroticism had a strong negative relationship with objectively measured physical activity which was not present for self-reported physical activity. It also imposed a suppression effect on the relationship between BIS and objective physical activity. After controlling for Neuroticism, a moderate positive effect was observed for objective physical activity and BIS.

This effect was suppressed by the stronger negative effect between physical activity Neuroticism, coupled with the strong positive relationship between BIS and Neuroticism. Individuals who scored high in Neuroticism and high in BIS had a similar physical activity level as those who scored low for Neuroticism and low for BIS, masking an observable effect for BIS unless Neuroticism was controlled. The positive association between BIS and physical activity did not support our suggestion that acute behavioral outputs of this system might predispose BIS dominant people be less active, despite a previous report that BIS is positively related to self-reported inactivity (Voigt et al., 2009) . Rather, an explanation for our observations may come from the motivational aspects of Gray's theory, which plausibly suggest that increments in BIS trait could encourage more physical activity, especially in environments or populations which place high importance on health, and/or physical appearance. For example, two individuals who both score high for Neuroticism could differ in their sensitivity to aversive cues, or cues of nonreward (i.e., high vs. low BIS). Though their level of Neuroticism predisposes them to participate in less physical activity, as is supported in the literature (Rhodes & Smith, 2006; Wilson & Dishman, 2014), the individual who is more sensitive to aversive cues (i.e. high BIS) may be more likely to act on negative reinforcers relative to health, physique, or athletic ability. The observed suppression effect suggests that BIS protects against risk for inactivity among those scoring high for Neuroticism, although longitudinal analyses would be required to support this inference.

The inverse relationship observed here between Neuroticism and physical activity measured by accelerometry disagrees with another report of a small, positive relationship observed in a small sample of obese females aged 40-64 years measured with accelerometry (Ohmori et al., 2007). Sample differences are the most likely contributor to this discrepancy.

The suppression effect of Neuroticism on the relationship between BIS and physical activity observed in our sample of college-aged females might be reversed in older, obese samples that may have higher motivation to improve their health and reduce stigma often associated with obesity by participating in physical activity.  Just as the relationship between Extraversion and self-reported physical activity vanished when we controlled for BAS in our sample, so might the inverse relationship between Neuroticism and objectively measured physical activity vanish by controlling for BIS in a sample for whom the negative consequences of inactivity are more salient.  Nonetheless, our findings are consistent with the size and direction of effects from the cumulative evidence regarding the association between physical activity and Neuroticism (Courneya, Friedenreich, Sela, Quinney, & Rhodes, 2002; Lochbaum, Litchfield, Podlog, & Lutz, 2013; Tolea, Terracciano, Milaneschi, Metter, & Ferrucci, 2012; Wilson & Dishman, 2014).

Our final tests, which specified models for confounding, mediation and moderation in the multivariate relationship between personality, physical activity and overall mental health, were guided by a preliminary model predicting mental health by personality to allow a test of the hypothesis that the observed relationship between physical activity and mental health is confounded with, or otherwise modified by, fundamental personality dimensions also related to mental health.  Effects for Extraversion and Neuroticism were similar to those of a previous report on mental health in a population cohort (Beard et al., 2007) as well as a meta-analysis clarifying the relationship between personality and subjective well being (Steel et al., 2008). Preliminary models supported the estimation of the final models separately for each physical activity factor.

Overall, results were similar for models of subjective and objective physical activity, though a 3-way interaction was observed in the models for objective physical activity that was not present for subjective physical activity, probably because of measurement error with the use of self-report methods. Fit for M2 (partial mediation) was better than M1 (confounded model) and M3 (full mediation with exogenous personality factors) across physical activity measurement methods. Models M4 and M5 were not supported as no significant interactions were observed for traits and self-report physical activity. Results from these analyses support a confounding effect of personality on the physical activity/mental health relationship. Model M2 indicates that personality directly effects both physical activity and mental health, and that the previously observed association between self-report physical activity and mental health is accounted for by their joint relationships with personality.

An interaction between objective physical activity and personality emerged as the most strongly supported model among those examining objective physical activity. Self-report measures may not be sensitive or accurate enough to indicate this interaction, even among a sample of young females for which self-reported physical activity is most congruent with objective measures (Dyrstad et al., 2014). Decomposition of the interaction revealed that physical activity was positively related to mental health only among neurotic introverts. This observation is consistent with reports that improvement in mental health outcomes with increased physical activity is dependent on baseline levels of mental health (Craft & Landers, 1998; Reed & Buck, 2009; Reed & Ones, 2006) as Neuroticism is a risk factor for developing a mental disorder such as anxiety or depression (Beard et al., 2007). Also, we observed a negative impact of physical activity level on mental health among stable introverts which was surprising, however still in alignment with theory. Introverts are more responsive to stimulation than are extraverts (Eysenck & Eysenck, 1985), and physical activity is physiologically stimulating. Neurotic introverts therefore represent a highly responsive anxiety prone group, for whom these data suggest physical activity protects from decrements in mental health similar to effects reported for training studies in clinical trials (Asmundson et al., 2013; Herring, O'Connor, & Dishman, 2010) and healthy adults (Conn, 2010). On the other hand, among stable introverts, the absence of Neuroticism seems necessary and sufficient to maximize mental health, and participation in physical activity among this hypersensitive yet stable group may act as an external stressor, which could be mentally disrupting and reflected in a diminished mental health score. It is important to note, however, that though active stable introverts report lower mental health than inactive stable introverts, they still report better mental health than those scoring high for Neuroticism, regardless of levels of Extraversion or physical activity.

Interrelations between mental health, physical activity level and personality most likely share some common genetic factors, though specific links have yet to be described. The effects of physical activity on mental health among neurotic and stable introverts may result from epigenetic responses to chronic activity levels, reflecting a modifying effect of physical activity on the relationship between personality and mental health. Conversely, individual differences in personality may make some people more responsive to exercise than others.

**Limitations.** The cross-sectional design does not allow for causal inferences, which poses a problem in understanding the observed interaction between personality and physical activity. That is, we don’t know if it’s physical activity that is modifying the relationship between personality and mental health, or if it’s personality that is modifying the relationship between physical activity and mental health. Furthermore, these observations are only generalizable to samples similar to our own, warranting replication studies in more diverse samples.  Also, the use of a general measure of depression and anxiety symptoms limits conclusions about other mental health outcomes or clinical samples.

**Conclusion.** Results from this study indicate that the relationship between physical activity and mental health depends on personality, in agreement with previous reports suggesting that the observed relationship between mental health and self-reported physical activity is confounded with personality (De Moor et al., 2006; De Moor et al., 2008). However, when physical activity was measured objectively by an accelerometer it interacted with personality to influence mental health.  Specifically, the positive effect of physical activity was observed only among neurotic introverts, acting to buffer the negative impact of Neuroticism in the absence of Extraversion.  Though, a negative impact of physical activity on mental health was observable only among stable introverts.

Replication studies are recommended using objective measures of physical activity in population-based prospective cohorts or randomized controlled trials in clinical samples, to determine the extent to which personality modifies the effect of physical activity on mental health, or conversely the extent to which physical activity protects against mental health risk among high risk personalities, such as neurotic introverts.

Table 3.1.
*CFA model fit statistics for psychometric measures and objective physical activity.*
IPIP: International Personality Item Pool; SF36 MH = SF-36 Mental Health score; PA: physical activity.

| | N | $\chi^2$ (df) | RMSEA (90% CI) | CFI | TLI | SRMR |
|---|---|---|---|---|---|---|
| Sample 1 | | | | | | |
| IPIP Full | 403 | 755.582 (169) | 0.093 (0.086, 0.100) | 0.826 | 0.804 | 0.071 |
| IPIP Trimmed | 403 | 190.953 (64) | 0.070 (0.059, 0.082) | 0.928 | 0.912 | 0.064 |
| BIS/BAS Full | 409 | 471.768 (166) | 0.067 (0.060, 0.074) | 0.825 | 0.800 | 0.087 |
| BIS/BAS Trimmed | 409 | 203.144(100) | 0.051 (0.041, 0.061) | 0.916 | 0.899 | 0.056 |
| Sample 2 | | | | | | |
| IPIP Trimmed | 297 | 126.836 (64) | 0.057 (0.043, 0.072) | 0.940 | 0.927 | 0.053 |
| BIS/BAS Trimmed | 295 | 163.904(100) | 0.047 (0.033, 0.059) | 0.926 | 0.911 | 0.065 |
| SF36 MH Full | 297 | 47.275 (5) | 0.169 (0.127, 0.214) | 0.872 | 0.745 | 0.064 |
| SF36 MH Trimmed | 297 | 0.004(2) | <0.001 (<0.001, <0.001) | 1.000 | 1.026 | 0.001 |
| Objective PA | 298 | 34.356(14) | 0.071(0.041, 0.101) | 0.952 | 0.928 | 0.043 |

Table 3.2.
*Bivariate correlations between latent variables for personality, physical activity, and mental health.*
$^a p<.05$, $^b p<.001$.
Samples 1 and 2 above and below the diagonal, respectively. SRPA: Self-reported physical activity; Obj PA = Objective physical activity; SF36 MH = SF-36 Mental Health score.

| | Extraversion | Neuroticism | BIS | BAS | SRPA | Obj PA | SF36MH |
|---|---|---|---|---|---|---|---|
| Extraversion | 1.000 | $-0.253^b$ | $-0.296^b$ | $0.400^b$ | -- | -- | -- |
| Neuroticism | $-0.307^b$ | 1.000 | $0.605^b$ | -0.128 | -- | -- | -- |
| BIS | $-0.169^a$ | $0.702^b$ | 1.000 | -0.108 | -- | -- | -- |
| BAS | $0.600^b$ | -0.004 | 0.110 | 1.000 | -- | -- | -- |
| SRPA | $0.222^b$ | -0.112 | 0.057 | $0.300^b$ | 1.000 | -- | -- |
| Objective PA | 0.037 | $-0.269^b$ | 0.021 | -0.015 | $0.292^a$ | 1.000 | -- |
| SF36 MH | $0.324^b$ | $-0.657^b$ | $-0.424^b$ | 0.012 | $0.169^a$ | $0.217^a$ | 1.000 |

Table 3.3.
*Structural parameters and equivalence statistics between samples.*
Top value = sample 1; bottom value = sample 2.

| Parameter | | Beta | SE | *p*-value | Wald statistic | *p*-value |
|---|---|---|---|---|---|---|
| Extraversion with | | | | | | |
| | Neuroticism | -0.259 | 0.057 | <0.001 | | |
| | | -0.306 | 0.067 | <0.001 | 0.010 | 0.9204 |
| | BAS | 0.397 | 0.062 | <0.001 | | |
| | | 0.578 | 0.090 | <0.001 | 2.088 | 0.1485 |
| | BIS | -0.300 | 0.064 | <0.001 | | |
| | | -0.147 | 0.084 | 0.080 | 2.869 | 0.0903 |
| Neuroticism with | | | | | | |
| | BAS | -0.133 | 0.069 | 0.053 | | |
| | | -0.034 | 0.091 | 0.372 | 1.035 | 0.3089 |
| | BIS | 0.601 | 0.070 | <0.001 | | |
| | | 0.704 | 0.058 | <0.001 | 0.910 | 0.3401 |
| BAS with | | | | | | |
| | BIS | -0.115 | 0.081 | 0.156 | | |
| | | 0.097 | 0.122 | 0.793 | 145393.800 | <0.0001 |

Table 3.4.
*Fit statistics for competing models of the structural relationship between personality, physical activity, and mental health according to physical activity measurement method.*

| | Self-report physical activity | | | | | |
|---|---|---|---|---|---|---|
| | $\chi^2$ (df) | RMSEA (90% CI) | CFI | TLI | SRMR | BIC |
| Confounded | | | | | | |
| M1 | 361.031(166) | 0.063(0.054, 0.072) | 0.885 | 0.869 | 0.077 | 20139.437 |
| Partial mediation | | | | | | |
| M2 | 352.331(164) | 0.062(0.053, 0.071) | 0.889 | 0.872 | 0.067 | 20141.386 |
| Mediated | | | | | | |
| M3 | 439.500(166) | 0.074(0.066, 0.083) | 0.839 | 0.816 | 0.124 | 20223.663 |
| Moderated | | | | | | |
| M4 (PA x N) | ------ | ------ ------ ------ | ------ | ------ | ------ | 20237.581 |
| M5 (PA x E) | ------ | ------ ------ ------ | ------ | ------ | ------ | 20236.580 |

| | Objective physical activity | | | | | |
|---|---|---|---|---|---|---|
| | $\chi^2$ (df) | RMSEA (90% CI) | CFI | TLI | SRMR | BIC |
| Confounded | | | | | | |
| M1 | 484.244(248) | 0.057(0.049, 0.064) | 0.890 | 0.878 | 0.076 | 33306.846 |
| Partial Mediation | | | | | | |
| M2 | 470.151(246) | 0.055(0.048, 0.063) | 0.896 | 0.883 | 0.062 | 33303.639 |
| Mediated | | | | | | |
| M3 | 554.467(248) | 0.064(0.057, 0.072) | 0.858 | 0.842 | 0.107 | 33381.940 |
| Moderated | | | | | | |
| M4 (PA x N) | ------ | ------ ------ ------ | ------ | ------ | ------ | 33306.034 |
| M5 (PA x E) | ------ | ------ ------ ------ | ------ | ------ | ------ | 33306.148 |
| M6 (PA x N x E) | ------ | ------ ------ ------ | ------ | ------ | ------ | 24067.596 |

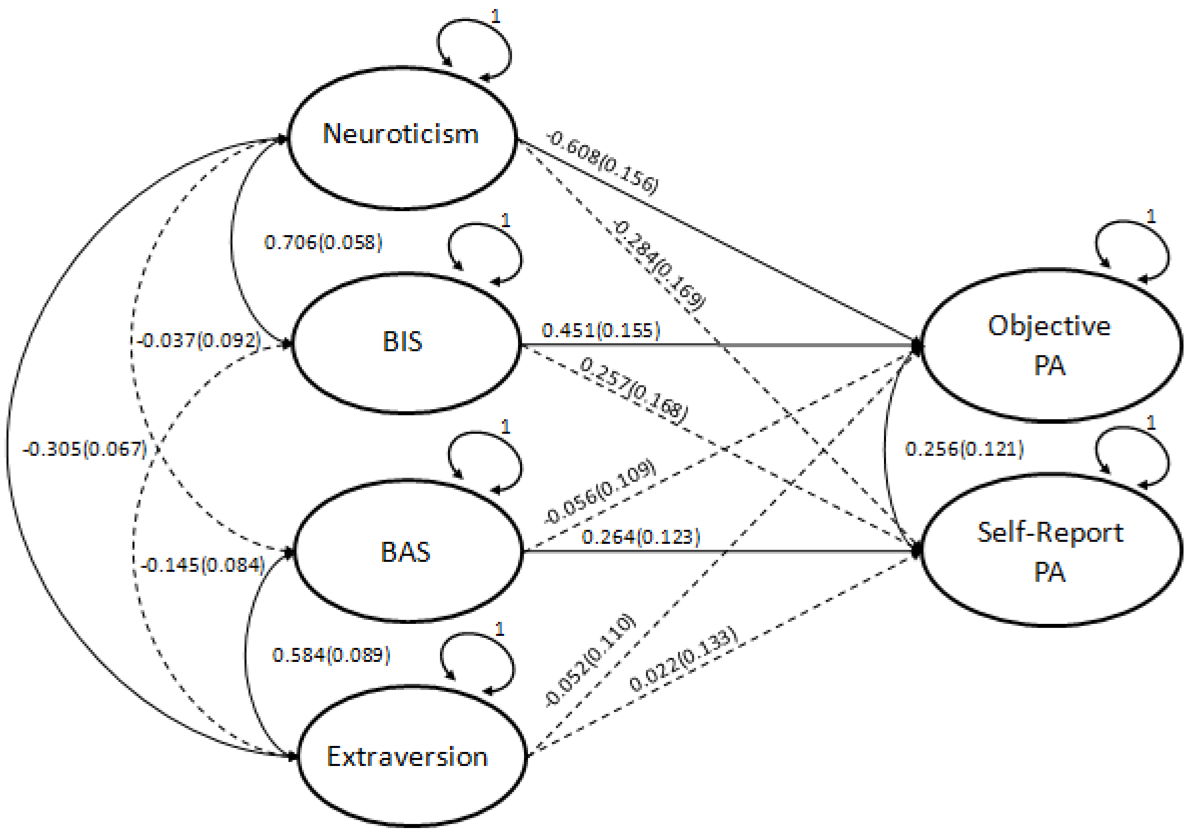


Figure 3.1.

*Structural model of the relationship between personality and physical activity measured objectively and subjectively.*

Broken lines indicate non-significant paths.

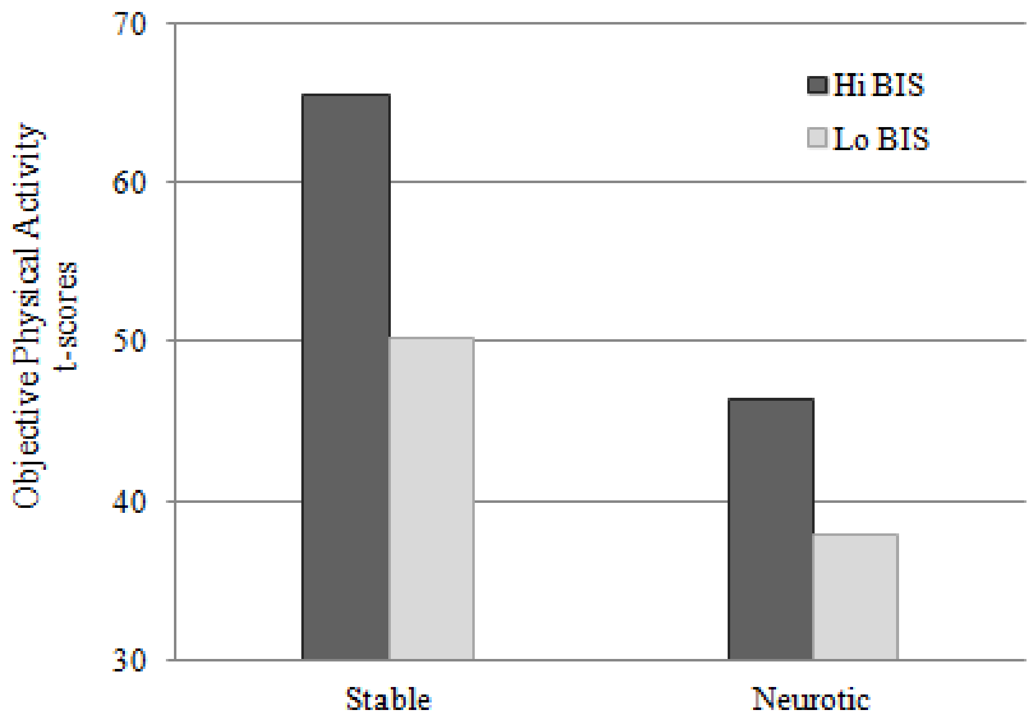


Figure 3.2.
*Moderation of the relationship between BIS and objectively measured physical activity by Neuroticism.*

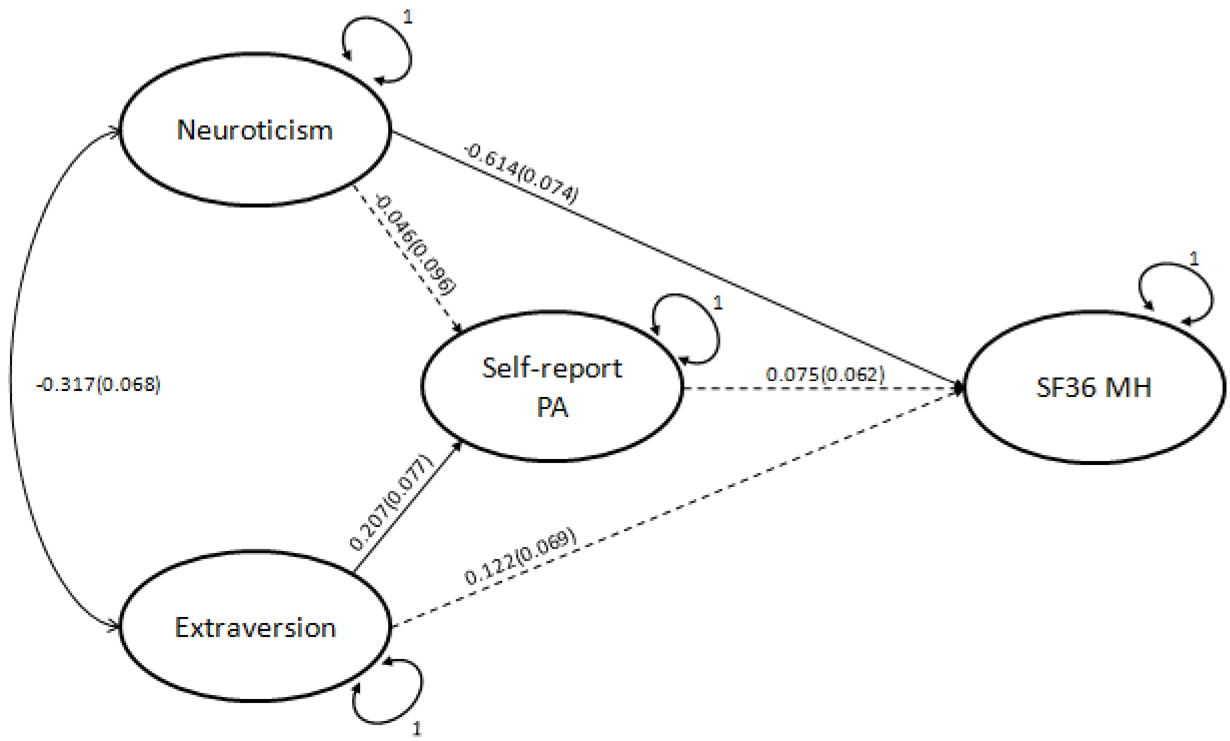


Figure 3.3.

*Structural model for the confounding effect of personality on the relationship between self-report physical activity and mental health.*

PA: Physical activity; SF36 MH: Mental health score from the SF-36. Broken lines indicate non-significant paths. Values represent standardized parameter estimates (standard error).

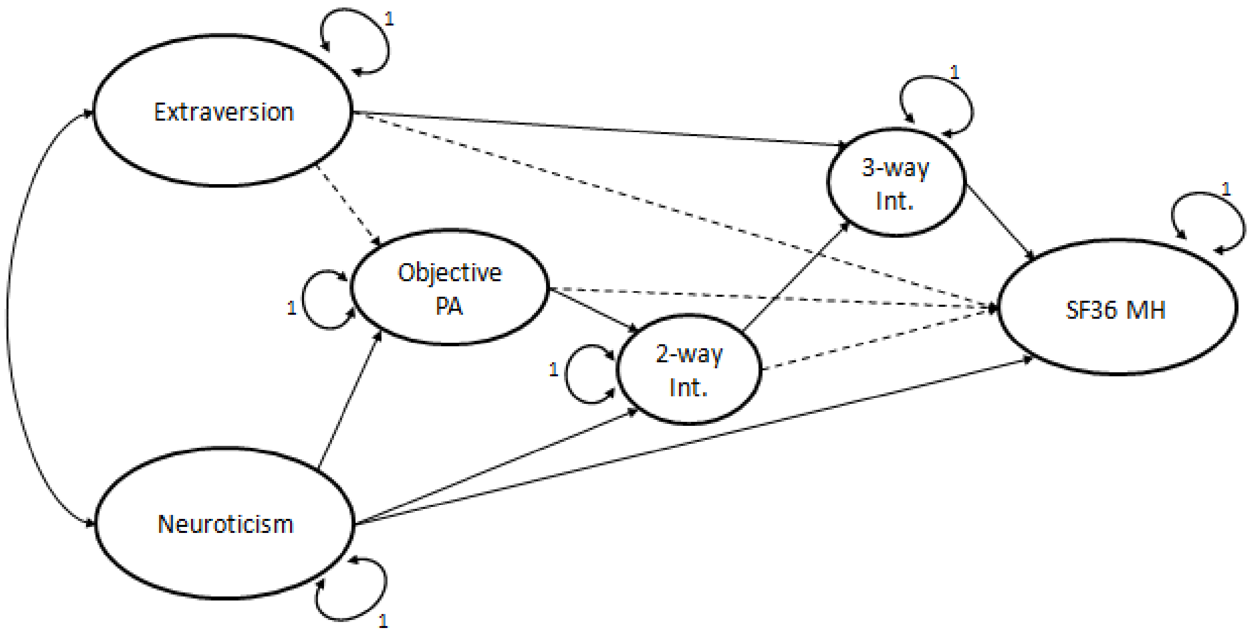


Figure 3.4.
*Structural model illustrating significant 3-way interaction between personality factors and objective physical activity predicting mental health.*
PA: Physical activity; SF36 MH: Mental health score from the SF-36; Int: Interaction.
Specification of the interaction term precludes the estimation of standardized parameter values.
Solid lines are significant ($p$ < .05).

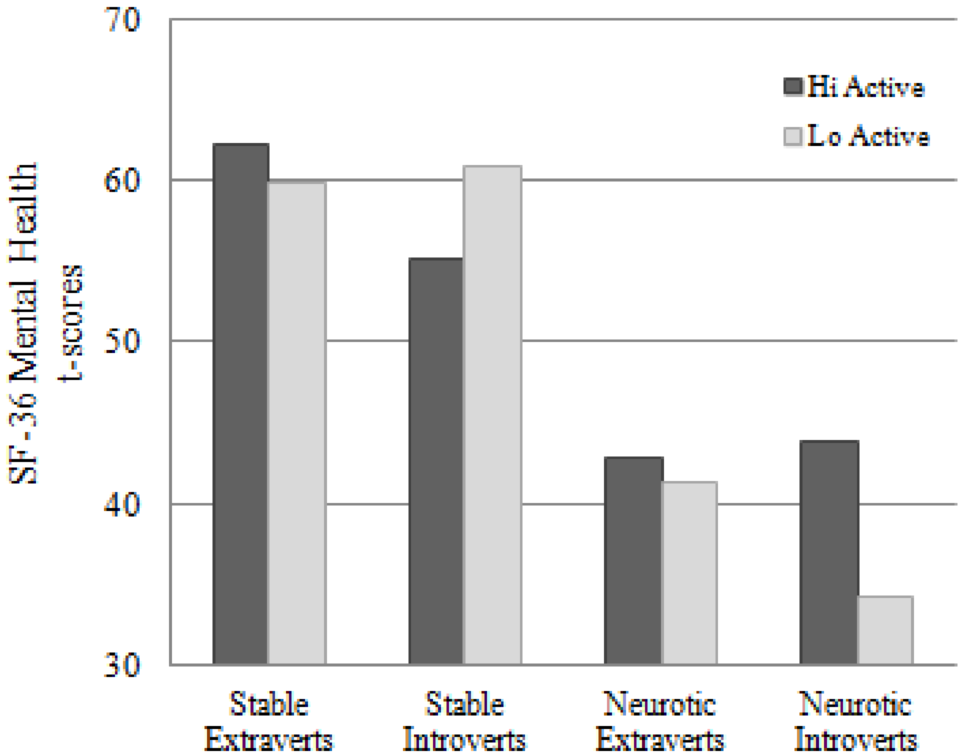


Figure 3.5.

*Decomposition of the 3-way interaction between objective physical activity, Neuroticism and Extraversion predicting mental health.*

# CHAPTER 4

**Affective Startle Modulation and Ratings of Affective Pictures after Exercise among People who Differ in Behavioral Inhibition and Approach Tendencies**

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**Abstract**

We examined valence-modification of the acoustic startle eyeblink and ratings of affect in response to affective pictures before and after moderate intensity exercise with and without perceived control, or quiet rest among 58 undergraduates (33 female) scoring high or low on measures of behavioral inhibition (BIS) or approach (BAS). Participants provided ratings of emotional responses to picture content. Our results agree with prior findings that emotional responding is unchanged after exercise when compared to a quiet rest condition, but extend the evidence to include exercise conditions in which participants are given a sense of control over the exercise intensity. Startle responses and ratings of valence support the conclusion that exercise does not alter the appraisal of picture content as appetitive or aversive. Ratings of arousal for neutral photos were increased after the perceived-control condition, but not the prescribed exercise condition or quiet rest. Though a significant 4-way interaction was observed for ratings of dominance, this was found to result from higher pre-condition ratings of unpleasant photos prior to prescribed exercise compared to other conditions among the high BAS group. Results suggest a mediating role of perceived control in arousal ratings of unpleasant stimuli after exercise. Expected personality differences in startle responses during picture viewing were not observed, bringing to question the validity of our grouping criteria. Replication is recommended to support or refute these observations, as there is little available evidence regarding the role of BIS/BAS traits in the effect of exercise on affective responses to aversive and appetitive stimuli.

**Introduction**

It is commonly agreed upon that moderately intense exercise improves affective experience (Berger & Motl, 2000; Byrne & Byrne, 1993; Ekkekakis, Parfitt, & Petruzzello, 2011; Giacobbi et al., 2005; Morgan, 1985; Moses et al., 1989; Roth, 1989; Steinberg et al., 1998; Yeung, 1996). A meta-analysis of 158 studies published from 1979 to 2005 on the effects of acute exercise on positive affect concluded that exercise increases positive mood (Reed & Ones, 2006). In particular, evidence indicates that acute exercise improves feelings of energy (Loy, O'Connor, & Dishman, 2013) and improves other moods in patients with depression (Bartholomew, Morrison, & Ciccolo, 2005), diabetes (Kopp et al., 2012) and spinal cord injury (Ginis & Latimer, 2007). These positive effects of exercise on mood have led to the presumption that an acute bout of exercise should result in observable changes in the way individuals process emotional stimuli. However, there is little experimental evidence to support this view.

Whether emotional responding or attention to an environmental threat or potential reward might be altered during or after exercise has only recently been studied. People are quicker to accurately detect both threatening and neutral, non-threatening images while exercising at either moderate or hard intensities (Shields, Larson, Swartz, & Smith, 2011). College students' attention to pleasant-looking faces was increased and attention to unpleasant faces was decreased while they cycled for about 10 minutes at a moderate intensity, but not a hard intensity (Tian & Smith, 2011). In contrast, moderately intense cycling exercise for 30 minutes by college students high in trait anxiety did not lower negative affect nor change their attention to positive scenes after the exercise ended, even though ratings of positive affect were increased (Barnes, Coombes, Armstrong, Higgins, & Janelle, 2010). Two other studies reported that neither low- or moderate-intensity exercise altered emotional responses to unpleasant or pleasant affective scenes (Crabbe, Smith, & Dishman, 2007; Smith, O'Connor, Crabbe, & Dishman, 2002). However, those studies did not control for the potential influence of individual differences such as personality on emotional responding. Here we report on a laboratory experiment to examine the effect of exercise on responses to emotional stimuli while controlling for personality traits indicative of sensitivity to appetitive or aversive cues.

Reinforcement Sensitivity Theory (Gray, 1982; Gray & McNaughton, 2000) clearly indicates that individuals with a high functioning behavioral inhibition system (BIS) are more sensitive to aversive or novel stimuli and exhibit stronger responses to those stimuli than someone with a relatively lower functioning BIS. Likewise, those with high levels of behavioral approach system (BAS) activity are more sensitive to appetitive cues, and exhibit an exaggerated response to signals of reward when compared to those with relatively lower BAS activation. Such responses manifest emotionally, behaviorally or both. Studies examining response to aversive and appetitive stimuli following exercise could provide evidence of exercise effects on functioning of the BIS and BAS, supporting the hypothesis that exercise improves affect via neurological pathways activating or inhibiting the BIS and/or the BAS.

Only a few methods provide an objective index for affect, one of which involves the electromyographic measurement of the acoustic startle eye-blink response (ASER). Occurring 30-40 milliseconds following the startle probe, ASER is an obligatory reflex that can be modulated by affective experience (Bradley, Cuthbert, & Lang, 1999). Consistent with Lang’s match-mismatch theory (Lang, Bradley & Cuthbert, 1990), ASER amplitude is reliably augmented in aversive states and diminished in appetitive states, relative to neutral states. Used in conjunction with appetitive or aversive stimuli, ASER provides a method to estimate sensitivity of the appetitive and aversive motivational systems (Lang, Bradley & Cuthbert, 1990), or the BIS and the BAS (Gray, 1982; Gray & McNaughton, 2000). If exercise were to act on these systems, it could be expected that changes in sensitivity to emotional stimuli would manifest for those stimuli to which one is naturally predisposed to attend; aversive stimuli among BIS-dominant, and appetitive stimuli for BAS-dominant individuals. In one study of valence-modulation of the ASER according to groups high and low in BIS or BAS trait, high scorers on either BIS or BAS evidenced more reliable ASER modification in the presence of motivational stimuli than did low-scorers. (Hawk & Kowmas, 2003). Specifically, valence-attenuated response was observed for pleasant photos among groups high in BIS or BAS. Another study reported significant valence-modulation of the ASER among groups high in anxiety (BIS) and low in impulsivity (BAS), but not among other personality groups (Corr, 2002).

The purpose of this experiment was to examine the possible moderating role of BIS/BAS traits on the effects of acute exercise on ASER valence-modification using a between groups repeated measure design. We expected that exercise would reduce the difference in ASER magnitude in the presence of unpleasant versus neutral photos compared to pre-condition response magnitude among the BIS-dominant groups. Likewise, among the BAS-dominant groups, we expected exercise to reduce the difference in ASER magnitude in the presence of pleasant versus neutral photos compared to baseline and following quiet rest. Extraversion and Neuroticism have a close relationship with BIS/BAS traits (Gray, 1982, 1991) and have a relationship with ASER (Blumenthal, 2001; Corr et al., 1995; Kumari et al., 1996; LaRowe, Patrick, Curtin, & Kline, 2006), and so were measured as covariates. If effects of exercise on ASER valence-modification are dependent on BIS and BAS functioning, they should remain significant after controlling for Extraversion and Neuroticism.

Subjective reports of affect are variable during exercise (Ekkekakis et al., 2011), and there is some evidence that BIS/BAS traits influence perceived exertion and affect during exercise (Hall et al., 2005; Schneider & Graham, 2009). Cognitive factors, such as perceived control and interpretation of exercise intensity, may mediate the effect of exercise on affective responses (Rose & Parfitt, 2007; Williams, 2008). We therefore included two exercise conditions: (1) a prescribed exercise condition in which the participants had no control over the exercise intensity, and (2) a perceived-control exercise condition during which participants were given opportunities to adjust their exercise intensity. Therefore, a secondary purpose was to see if perceived control during the exercise bout mattered for exercise effects on emotional responding.

## Methods

**Recruitment**. Protocols were approved by the Institutional Review Board. Students were contacted via their UGA email address and invited to participate in the study. After informed consent to participate in the screening, they were given access to the self-report measures (SurveyMonkeyInc, 2011-2013) and instructed to complete only one or two surveys at a time over the following seven days in the order of their preference. Inclusion required participants to be undergraduates at the University of Georgia between the ages 18-25 years, and belong to one of four personality groups as indicated by scores on the BIS/BAS scales: (1) low BIS, (2) high BIS, (3) low BAS, and (4) high BAS. Personality groups were defined as scores greater than or equal to 1 SD away from the mean of either BIS or BAS, and a score of equal to or less than 0.5 SD away from the mean on the other scale, respectively, using the gender and age group norms provided by Jorm et al. (1999). For example, a HI BIS participant would score greater than or equal to1 SD above the age and gender matched mean for BIS, while also scoring less than or equal to 0.5 SD from the age and gender matched mean for BAS. These criteria provided a wide range for each behavioral system, while limiting the interaction between systems within groups. Participants with more than one risk factor for cardiovascular disease were ineligible as were individuals seeking clinical treatment for psychological disorders, and anyone taking psychoactive drugs.

**Participants.** A total of 618 undergraduates were screened, 125 of which were invited to participate. Of those, 78 were enrolled (i.e. gave informed consent to participate in the experiment and participated in at least one of the four visits). Twenty participants dropped out of the study for various reasons: 1 participant was intolerant of the auditory startle probe, 2 dropped because we were unable to achieve impedance of <10 kohms after a maximum of three attempts per visit attempted on more than one occasion, 2 were disqualified because of preexisting conditions not covered in the screening questionnaires which would alter response magnitude in the acoustic startle eyeblink reflex (e.g. Tourette's syndrome), 3 participants dropped citing an adverse skin reaction to the electrode placement procedure, 5 participants decided to quit without citing a specific reason, and 7 participants completed one or more visit but did not return to complete all four visits nor did they respond to contact attempts. A total of 58 undergraduates from the University of Georgia completed the experimental protocol. Descriptive statistics for the final sample are displayed in Table 1.

**Measurement Tools.**

***BIS/BAS Scales.*** The BIS/BAS Scales (Carver & White, 1994) were used to assign participants to personality groups. Items on the BIS/BAS scales are presented in full sentence form, with a forced answer 4-point ordered scale ranging from "very true for me" to "very false for me." Evidence for the validity of this scale is extensive (Berkman, Lieberman, & Gable, 2009; Campbell-Sills, Liverant, & Brown, 2004; Carver & White, 1994; Caseras, Àvila, & Torrubia, 2003; Cooper, Gomez, & Aucote, 2007; Gable et al., 2000; Heubeck et al., 1998; Leone, Perugini, Bagozzi, Pierro, & Mannetti, 2001; Torrubia, Ávila, Moltó, & Caseras, 2001; Zuckerman, Joireman, Kraft, & Kuhlman, 1999). Internal consistency was supported in our sample for BIS (α=.801) and BAS (α=.820) scales.

***IPIP.*** Extraversion and Neuroticism were assessed using the International Personality Item Pool (IPIP). Each trait was measured with ten items using a 1-5 Likert-type response format (Goldberg, 1999; Goldberg et al., 2006). Adequate reliability was demonstrated in our sample for Extraversion (α=.911) and Neuroticism (α=.916).

***Cardiovascular risk***. Screening for contra-indications to exercise was accomplished with the Physical Activity Readiness Questionnaire (Cardinal, Esters, & Cardinal, 1996; Thomas, Reading, & Shephard, 1992) and the AHA/ACSM Health/Fitness Facility Pre-participation Screening Questionnaire (American College of Sports Medicine, 1998).

***Physical Activity***. The Godin Leisure Time Exercise Questionnaire (GLTEQ) was used to measure moderate to vigorous leisure time physical activity (Dishman et al., 2010; Godin & Shephard, 1985).

***Indirect Calorimetry.*** Oxygen consumption was measured with standard procedures using a Sensor Medics metabolic cart (PARVO Medics, Sandy, Utah). Fitness ($VO_{2peak}$) and ventilatory threshold were measured during a maximal graded stationary cycle test (Whaley, Brubaker, & Otto, 2006). Oxygen consumption ($VO_2$ mL/kg/min) was also measured during the conditions to check for differences in exercise condition intensity relative to ventilatory threshold, and to confirm that the participant was at or near the prescribed exercise intensity.

***RPE.*** Borg's 6-20 category scale (Borg, 1998; Chen, Fan, & Moe, 2002) was used to obtain ratings of perceived exertion (RPE) during the maximal exercise test, as well as every three minutes during the 20-minute exercise bouts and quiet rest during the three conditions.

***Affective pictures.*** Seven presentations of affective pictures (one familiarization presentation, and 6 randomly assigned experimental presentations) were used to manipulate emotional state. Participants viewed each presentation on a screen approximately 21" in front of their face while seated in a semi-recumbent position. Each affective presentation included 54 photos; 12 unpleasant, 12 pleasant, and 12 neutral photos chosen from the International Affective Picture System (IAPS) image pool (Lang, Bradley, & Cuthbert, 2008), and 6 positive, 6 negative, and 6 neutral photos from the NimStim image pool of facial expressions (Tottenham et al., 2009). All unpleasant and pleasant photos were rated as highly arousing (Cuthbert, Bradley, & Lang, 1996), and each photo was only viewed once throughout the experiment (Larson, 2000). Photos of similar valence were presented in clusters of 3 (Bradley, Cuthbert, & Lang, 1996; Sutton, Davidson, Donzella, Irwin, & Dottl, 1997). The first photo in each cluster was a NimStim photo which served as a visual short lead anticipatory stimulus, and appeared for one second. The second and third photos were IAPS images and served as long lead interval stimuli for acoustic startle eyeblink response used as a probe of emotional processing (Bradley, Codispoti, & Lang, 2006; Bradley, Cuthbert, & Lang, 1993). Each IAPS photo appeared for 6 seconds. The interphoto interval within each cluster was 2 seconds. Participants were asked to rate the clusters for arousal, valence and dominance using the SAM scales (described below). Ratings were followed by a random intercluster interval ranging between 3-5 seconds. Presentations lasted between 8 minutes and 55 seconds and 17 minutes and 35 seconds, depending on how long each participant took to respond to the SAM scales.

***SAM***. The Self Assessment Manikin rating scales (Bradley & Lang, 1994) are analog scales used to measure subjective reports of affective valence, arousal and dominance. Participants rated each cluster of photos in the affective presentations using these scales. Reported norms (Lang et al., 2008) for the slides employed were used to confirm that the slide content was being perceived as intended. Scores were used as a manipulation check as well as an outcome measure. High scores indicate increased arousal, negative valence, and dominance.

***Acoustic Startle Probe***. The acoustic startle probe was administered once per photo during each affective presentation. The second and third photo in each cluster were accompanied by a startle probe administered randomly between 2.5 and 5.5 seconds following photo onset (Bradley et al., 1993). This 50 ms, 95 dB burst of white noise produced by a Coulbourn Instruments audio source module (model V85-05) and amplified by a RadioShack 40 watt P.A. amplifier, was delivered binaurally through Sony model MDR-V200 dynamic stereo headphones, with an instantaneous rise/fall time (Berg & Balaban, 1999). The intensity of the acoustic stimulus was calibrated at the surface of the headphone using a sound level meter (General Radio Company, Concord Massachusetts) prior to participant arrival.

***Electromyography (EMG)***. EMG recordings of the obicularis oculi provided recordings of the acoustic startle eyeblink response during each affective presentation. Skin preparation for EMG measurements proceeded as recommended by Fridlund and Cacioppo (1986). The surface of the skin was lightly abraded using Nuprep abrasive skin prepping gel and alcohol swabs. Two miniature biopotential skin electrodes, were filled with Mansfield R & D TD-40 electrode gel with saline, and attached 5 mm lateral from the exocanthion and 10 mm medial and 5 mm inferior to that location for measurements of the orbicularis oculi. Electrode impedance was verified as less than 10 kohm using a Grass electrode impedance meter (model EZM 4). A grounding electrode was placed medially on the forehead below the hairline. Raw EMG signals were amplified 100 times using a Grass P5 series AC amplifier, routed to a Kenwood digital storage oscilloscope (CS-8010), digitized at 1000 Hz, and displayed digitally using Spike2 version 6.08 software. Recorded data included the mean amplitude and its standard deviation for the 1 second prior to probe onset, amplitude at probe onset, and peak amplitude within a response window of 20-100 milliseconds after probe onset. All amplitude measures were integrated, rectified, and expressed in millivolts. Response amplitude was designated as the difference between amplitude at probe onset and peak amplitude within the response window. Trials with excessive background noise and trials during which the subject was blinking at the time of probe onset were deemed invalid and excluded. Excessive background noise was defined as trials for which the standard deviation of the amplitude during the 1 second prior to probe onset was greater than or equal to 3 SD from the mean standard deviation within each subject per visit. After the excessive noise exclusion, trials during which the subject was blinking during probe onset were identified as those for which the amplitude at probe onset was greater than or equal to 3 SD from the mean amplitude of the 1 second prior to probe onset for each trial. Finally, response amplitudes less than 2 SD from the amplitude at probe onset were considered non-responses and excluded. A total of 661 startles were excluded because of excessive noise or blinking, and an additional 1,021 trials were excluded as non-responses leaving a total of 17,110 valid startles. Coefficients of variation for the 1 second prior to probe onset for included trials ranged from 1.00-15.63. Response magnitude was calculated as the product of mean response amplitude in millivolts and the response probability ($mM=mA*P$) where response probability represents the proportion of valid responses for each level of slide valence to total possible responses for the respective valence (Blumenthal et al., 2005).

Response magnitudes were transformed and expressed as z-scores within each participant for each day of testing to control for differences in basal EMG activity between subjects, and within subjects across visits.

**Procedure.** Participants completed 4 laboratory visits scheduled at least 3 days apart. On visit 1, participants provided informed consent and were taken through a familiarization affective presentation, followed by a graded maximal exercise test. Each participant pedaled between 60-80 rpm on a Lode mechanically-braked cycle ergometer. After a 5-minute warm up at 35W, the power output was increased to 99W and then incremented by 33W every 2 minutes until volitional fatigue or an inability of the participant to maintain prescribed pedal rate. Peak heart rates were ≥85% of age- predicted maximum except for 3 participants who all reached ≥80%, and respiratory exchange ratio exceeded 1.1 for all participants. Visits 2 through 4 proceeded similarly, starting with electrode placement and impedance check, followed by a randomly assigned pre-condition affective presentation. After the presentation, the participants completed one of three randomly assigned conditions (described below). Each condition lasted a total of 30 minutes. After each condition, participants were offered a cup of water, and a towel. We then confirmed that impedance was still below 10 kohm before administration of the randomly assigned post-condition affective presentation. Rarely, electrodes were replaced in cases that impedance had increased above the criteria. All participants began the post-condition affective presentation 5 to 8 minutes after cessation of each condition. After the second presentation, the EMG electrodes were removed and the participant was reminded of their next scheduled visit, if applicable.

Participants completed three randomly assigned conditions, quiet rest and two exercise conditions: a constant intensity exercise bout (prescribed condition) and a bout during which the participant was allowed to change the intensity by requesting a small (5 watt) or large (10 watt) change in intensity (perceived-control condition). Both bouts were completed on a Lode electronically-braked cycle ergometer, and began with a 2-minute rest period during which we measured ‘resting’ $VO_2$, a 4-minute warm-up at 30 watts, a 20-minute exercise bout, and a 4 minute cool-down at 30 watts. Participants were instructed to maintain a pedal rate of 60-80 rpm throughout the exercise bouts. Exercise intensity during the prescribed condition was set to elicit an oxygen consumption of about 60% $VO_2$peak, as it was for the first 6 minutes of the perceived-control exercise bout after which participants were given the choice to reduce, maintain, or increase resistance by “a lot” (10 watts) or “a little” (5 watts) every four minutes until the end of the 20-minute bout (5 times total). Exercise intensity relative to fitness or ventilatory threshold did not differ between the exercise conditions, providing confidence that any differences in responding after the two exercise bouts could be attributed to a greater sense of control during the perceived-control condition. Participants maintained a pedaling rate between 60 and 80 RPM. We also measured $VO_2$ for one minute halfway through the condition, and again for one minute just prior to cool-down.

The control condition lasted 30 minutes and mimicked the exercise conditions with the exception of exercise. Participants sat quietly on the stationary cycle and provided $VO_2$ measurements at the same time points as described above. Participants were instructed to be generally still, but feel free to adjust their position to be comfortable while on the bike.

**Statistical analyses.** Statistical analyses were conducted using IBM SPSS version 21. The outcomes of interest were mean response magnitudes and ratings of arousal, valence, and dominance according to slide content for each pre- and post- condition presentation. We used 4 (group) X 3 (valence) X 3 (condition) X 2 (time) mixed-model ANOVAs to test the hypothesis of between group differences in changes in emotional modulation of ASER magnitude and affective ratings. Gender, Extraversion, Emotional Stability, and physical activity level were examined as covariates. Interactions were decomposed using orthogonal polynomial contrasts. In the case of a significant F-test, we conducted follow-up RM-ANOVAs. Effects are reported with test statistics and their respective *p*-values. When assumptions of sphericity were violated we reported epsilon and Huynh-Feldt corrected estimates.

**Results**

**Manipulation checks.** Mean (sd) ratings of arousal, valence, and dominance in response to the different slide contents were averaged across presentations for the total sample as well as by personality group and are displayed in Table 2 along with summarized normative data for the IAPS slides employed (Lang et al., 2008). Subjective ratings of slide content within our sample were similar to those reported in the normative sample. Condition descriptions for exercise intensity were expressed for the final $VO_2$ measurement as a percentage of $VO_2$peak and ventilatory threshold. These values along with average RPE per condition are displayed as means (sd) in Table 3. Values indicate that participants exercised at about 60% $VO_2$peak during both exercise conditions. Bivariate correlations for personality variables, physical activity level and fitness are listed in Table 3.

**Response Magnitude.** Results from the 4 way mixed-model ANOVA for response magnitude indicated a main effect for valence [$F(2, 108) = 16.213$, $p < .001$, $\varepsilon = .974$], consistent with expected effects of picture content. There was also a main effect of time [$F(1, 54) = 48.113$, $p < .001$, $\varepsilon = 1.0$], indicating that eyeblink responses were reduced after each condition. There were no effects of personality. There was also a quadratic X quadratic X linear 3-way interaction between valence, condition and time [$F(1, 54) = 7.657$, $p = .008$, $\varepsilon = .910$]. The interaction remained significant after adjusting for gender [$F(1, 53) = 5.285$, $p = .025$], Extraversion [$F(1, 53) = 4.977$, $p = .030$, $\varepsilon = .912$], and Emotional Stability [$F(1, 53) = 8.358$, $p = .006$, $\varepsilon = .939$], but not leisure time moderate-to-vigorous physical activity [$F(1,50)=3.310$, $p=.075$, $\varepsilon =.918$], which was lower among participants who scored high on BIS and higher among those scoring high on BAS (see Table 5).

**Subjective ratings.** A significant 3-way (valence X condition X time) interaction for subjective ratings of arousal in response to the affective presentation was revealed by the 4-way ANCOVA after adjustment for Extraversion, Emotional Stability, gender, and leisure time moderate to vigorous physical activity [$F(1, 47)=4.815$, $p=.033$, $\varepsilon = 1.0$]. Plot inspection (Figure 2, panel A) led to a 3(valence) X 2(condition) X 2(time) ANOVA between the perceived-control exercise condition and the other two conditions combined, which supported significant valence X condition [$F(1, 57)=6.327$, $p=.015$, $\varepsilon=.889$], and condition X time [$F(1,57)$=10..596, $p=.002$, $\varepsilon=1.0$] interactions. Follow-up 2-way (time X condition) ANOVAs conducted separately for each valence showed that arousal ratings for unpleasant [$F(1, 57)=6.171$, $p=.016$, $\varepsilon=1.0$] and neutral [$F(1, 57)=5.506$, $p=.022$, $\varepsilon=1.0$] photos were significantly higher than pre-condition after the perceived-control condition, but not after the control or prescribed exercise conditions. Finally, repeated measures one-way ANOVAs revealed that pre-condition arousal ratings of unpleasant photos were lower prior to the perceived control condition than prior to either prescribed exercise or quiet rest conditions, whereas there was no difference in pre-condition arousal rating of neutral photos. Arousal ratings for pleasant photos did not significantly change after any condition.

The 4-way ANOVA for valence ratings supported a main effect for picture valence [$F(1, 57)=13.831$, $p<.001$, $\varepsilon=.571$] and a condition X time interaction [$F(1, 57)=4.755$, $p=.033$, ε=.989]. The interaction was not significant after adjusting for Extraversion or Emotional Stability ($p$<.05). Plots for the time effect across photo content for each condition are presented in Figure 2, panel B.

A significant 4-way interaction (group X valence X condition X time) was observed for ratings of dominance [$F$(3, 54)=2.808, $p$=.048] and remained significant after adjusting for Extraversion, Emotional Stability, gender, and leisure time moderate to vigorous physical activity [$F$(3, 47)=3.130, $p$=.034]. Follow up analyses revealed a significant 3-way (valence X condition X time) interaction in the high BAS group only [$F$(1, 14)=7.707, $p$=.015, ε=.909]. The high BAS group was then compared to the other three groups collapsed, and the 4-way interaction remained significant [$F$(1, 56)=8.012, $p$=.006]. Figure 3, panel A displays plots for dominance ratings pre- and post-condition for the high BAS group, and panel B shows plots for the rest of the sample. This effect appeared driven by a significant condition X time interaction for unpleasant photos within the high BAS group [$F$(1, 14)=13.079, $p$=.003, ε=.759] that was absent in all other participants. Ratings of dominance in response to unpleasant photos were lower among the high BAS group after the prescribed exercise condition than they were prior, whereas ratings increased following the quiet rest and perceived-control exercise conditions. A follow up repeated measured one-way ANOVA revealed that dominance ratings prior to the prescribed exercise condition were higher than they were prior to the perceived-control exercise and quiet rest conditions.

**Discussion**

Our results agree with the few prior reports that emotional responding is generally unchanged after exercise when compared to control conditions (Barnes et al., 2010; Crabbe et al., 2007; Smith et al., 2002). We extend this evidence to include exercise conditions in which participants are given a sense of control. ASER responses and subjective ratings of valence support the conclusion that exercise does not alter the appraisal of picture content as appetitive or aversive. The perceived-control exercise condition resulted in an increase in ratings of arousal for neutral photos that was not observed with prescribed exercise or quiet rest. Here we also provide the initial report on dominance ratings of pictures of varying content after exercise conditions or quiet rest.

The hypothesis that effects of exercise on responses to motivational stimuli are present but masked by individual differences in sensitivity to aversive and appetitive cues was not supported. A direct test of this hypothesis may have been precluded by the absence of group effects in valence-modification of the ASER observed in our sample. Though the expected pattern of responses was present across the entire sample, the anticipated group differences according to Reinforcement Sensitivity Theory (Gray, 1982, 1991; Gray & McNaughton, 2000) were absent. Ours is not the only study to report a failure to produce expected personality effects on ASER valence-modification (Kumari et al., 1996). Other reports suggest that valence-modification may be observable only for groups with high BIS activity (Corr, Kumari, Wilson, Checkley, & Gray, 1997; Corr et al., 1995). It is possible that our grouping criteria were not adequately extreme, or that exclusion of subjects seeking help for mental distress limited our sample such that variation in BIS and BAS activity was insufficient to produce the expected personality effect on ASER valence-modification. It is also possible that expected group differences are dependent on the interaction of BIS and BAS within subjects (Corr, 2001, 2002). We aimed to isolate effects for high functioning of either BIS or BAS while controlling for functioning in the other respective system (i.e. BIS or BAS) under the conventional prediction of separable subsystems hypothesized in Gray's theory. This could have impacted the responsiveness within groups by restricting interaction effects between the traits, as proposed in the joint subsystems hypothesis (Corr, 2001). Observable effects of personality on valence-modification of the ASER might require the full range of trait interactions. Likewise, the moderating role of personality in the effect of exercise on emotional processing may depend on an interaction between traits.

Another possibility is that scores on the BIS/BAS scales represent a necessary yet insufficient grouping criterion for individual differences in BIS and BAS functioning. The BIS/BAS scales are currently the most commonly used scales for BIS and BAS traits, and they boast extensive evidence of validity (Berkman et al., 2009; Campbell-Sills et al., 2004; Carver & White, 1994; Caseras et al., 2003; Cooper et al., 2007; Gable et al., 2000; Heubeck et al., 1998; Leone et al., 2001; Torrubia et al., 2001; Zuckerman et al., 1999). However convergent evidence from psychophysiological, psychopharmacological and functional neuro-imaging studies is mixed (Brenner, Beauchaine, & Sylvers, 2005; Harmon-Jones & Allen, 1997; Heponiemi, Keltikangas-Jävinen, Kettunen, Puttonen, & Ravaja, 2004; Reuter et al., 2004; Stuettgen, Hennig, Reuter, & Netter, 2005). A long standing problem for Reinforcement Sensitivity Theory is the absence of a measure developed by the theorist, and therefore no ‘official’ widely accepted psychometric measure of its traits, which has led to widespread heterogeneity in measures used and reported results (for a review, see Torrubia, Ávila, & Caseras, 2008). Norms used to set grouping criteria for the present study were published in an observational report (Jorm et al., 1999) of the factor structure and scale correlations with related psychometric constructs (e.g. Extraversion, Neuroticism). A stronger test of our hypothesis might come from an adaptation of this design to include a psychophysiological or behavioral correlate of BIS and BAS functioning as a screening tool to be used in conjunction with valid psychometric measures, which may be limited by ceiling and/or floor effects. For the sake of consistency and comparability between studies, the use of a popular instrument with evidence of validity, such as the BIS/BAS scales, is a defensible practice, but may be insufficient to use as a grouping criterion on its own.

Conversely, there really could be no effect of exercise on subsequent valence-modification of the ASER regardless of individual differences in BIS/BAS traits. The cumulative evidence supports this possibility (Barnes et al., 2010; Crabbe et al., 2007; Smith et al., 2002). One avenue not yet explored among studies testing exercise effects on emotional responding is that of preferred-intensity exercise. Effects have been reported for cycling at 40%, 50%, and 70% $VO_2$peak (Crabbe et al., 2007; Smith et al., 2002), and at 70% of heart rate reserve (Barnes et al., 2010). We had participants cycling at 60% $VO_2$peak with and without opportunities to request a change in intensity, though the increments of change set by the researcher were too small to elicit a significant difference in intensity between the two conditions. Thus our manipulation aimed to influence perceptions of control without allowing the participant to change the exercise prescription. Control over the exercise bout has been indicated as an important factor in affective responses to exercise (Rose & Parfitt, 2007), though this evidence was presented in reference to a self-paced condition. It is unclear whether participants or groups even, in our sample were able to attain their 'preferred' exercise intensity. This could be relevant as some individuals will adjust exercise intensity to maximize affective pleasure and minimize discomfort (Cabanac & Leblanc, 1983), and effects of exercise on subsequent responding to emotional stimuli may be dependent on subjective responses during the exercise bout which have been observed to vary according to BIS/BAS traits (Hall et al., 2005; Schneider & Graham, 2009). Research is needed to determine whether emotional processing during or after exercise is optimized with a self-paced protocol, and whether that pace and therefore those effects differ according to personality.

We report an increase in ratings of arousal for neutral photos after the perceived-control exercise condition, but not the prescribed exercise or quiet rest conditions. A recent qualitative analysis of individual differences in affect change during and after exercise at various intensities identified cognitive factors underpinning variation in affective responses to exercise (Rose & Parfitt, 2007). Among these was perceived control. Perceptions of control may therefore mediate post exercise changes in general arousal, reflected in their ratings of neutral photos, without altering arousal responses to emotional stimuli. Support for this hypothesis is found in a recent meta-analysis reporting increased levels of energy state after exercise (Loy et al., 2013), though the potential mediation of these effects by perceptions of control during the exercise bout has yet to be empirically tested.

Effects observed for arousal ratings of unpleasant photos resulted from differences in ratings at the pre-condition time point. Our failure to observe significant effects of exercise on arousal ratings of unpleasant photos conflicts with a previous report of decreased arousal ratings to unpleasant stimuli after moderate-intensity prescribed exercise compared to quiet rest among healthy adults (Crabbe et al., 2007). It is unclear why we failed to observe a similar reduction after our prescribed-intensity exercise condition as was previously reported. Changes in affect during exercise are expected to influence affect after exercise, as well as subsequent participation in physical activity (i.e. adherence; Ekkekakis et al., 2011; Ekkekakis & Petruzzello, 1999). Also, there is a reduction in affective valence during exercise at increasing intensities, and exercise at or near ventilatory threshold produces variable affective responses (Ekkekakis et al., 2011; Parfitt, Rose, & Burgess, 2006; Rose & Parfitt, 2007). One possibility is that the slightly higher intensity of the prescribed bout in our study, compared to theirs, might have altered the affective experience during exercise enough to blunt the post exercise change in arousal ratings of unpleasant stimuli.

In light of the available evidence, our observations support a test of the hypothesis that the impact of acute exercise on arousal ratings is mediated or moderated by properties of the exercise stimulus, such as intensity and control (i.e. self-selection of the intensity), and/or cognitive factors identified as mediators of the affective response to exercise (e.g. perceived control, interpretation of intensity, expected benefit, etc.). Identifying effect modifiers of emotional responding during and after exercise could be essential to the development of widely successful physical activity interventions, and provide the 'missing link' for laboratory studies testing the effect of exercise using affective and cognitive probes, such as ASER or the dot-probe task, in search of evidence for the mechanisms through which exercise exerts its mood enhancing effect.

Interpretations of this preliminary evidence are purely speculative considering the current absence of reports on individual differences in, and the effect of exercise on, ratings of dominance. However, it appears that exercise, with or without perceptions of control, has no effect on dominance ratings of emotional stimuli. More work should be done to replicate or refute this null observation.

**Limitations.** The absence of expected group difference in valence-modification of the startle response is a limitation and suggests that our grouping criteria may have been insufficient to test the main hypothesis. Exclusion of those seeking help for mental distress, and/or our grouping paradigm guided by the conventional separable subsystems hypothesis, may have limited our ability to observe true effects relative to our hypothesis. A weakness of this study is the failure to conduct a manipulation check for perceptions of control during the perceived-control exercise condition. Though we did not attempt to measure the extent to which perceptions were changed, our manipulation for perceptions of control has face validity. But, until this is replicated, our interpretations regarding the effects of perceptions of control during acute exercise, and their influence on affective responding after exercise, are premature.

**Conclusion.** Consistent with prior reports, results reported here suggest that emotional responding is generally unchanged after exercise when compared to control conditions. A significant condition X time interaction was not observed among any of the personality groups for ASER responses or ratings of valence, suggesting that exercise does not alter the appraisal of photos as pleasant or unpleasant, regardless of individual differences in BIS/BAS traits. An increase in ratings of arousal for neutral photos after the perceived-control condition, but not the prescribed-exercise or quiet rest conditions, supports a possible mediating effect of perceptions of control during exercise on resulting affective changes. Dominance ratings were unchanged, but a paucity of evidence warrants replication. Interpretations regarding the role of perceived-control during acute exercise, and its influence on affective responding after exercise, are premature. The absence of group differences according to personality may indicate that trait level sensitivity to punishment and reward does not alter affective responses to exercise. Conversely, our grouping criteria may not have been sufficient to test this hypothesis. Replication studies are recommended to rule out this possibility, and to determine the impact of cognitive factors that may modify the affective response to acute exercise. The use of a physiological or behavioral correlate of BIS/BAS in conjunction with psychometric classification could improve the accuracy of grouping criteria and reveal the expected modifying effect of personality on affective responses to exercise.

Table 4.1.
*Descriptive statistics for the total sample and each personality group*.
Values are means and standard deviations unless otherwise specified. MVPA score is a sum of moderate and vigorous leisure time physical activity scores as indicated by the GLTEQ.

| | Total Sample | Low BIS | High BIS | Low BAS | High BAS |
|---|---|---|---|---|---|
| N | 58 | 15 | 15 | 13 | 15 |
| Females (n) | 33 | 7 | 8 | 8 | 10 |
| Age | 20.5 (1.6) | 20.1 (1.8) | 20.7 (1.8) | 21.2 (1.6) | 20.0 (1.1) |
| BIS | 19.7 (4.0) | 15.1 (2.9) | 24.1 (2.3) | 19.5 (2.1) | 20.1 (1.5) |
| BAS | 39.7 (5.2) | 38.5 (2.6) | 38.7 (2.7) | 34.3 (3.3) | 46.6 (2.8) |
| Extraversion | 32.2 (7.7) | 37.1 (4.0) | 27.9 (9.3) | 28.8 (5.7) | 34.5 (7.2) |
| Stability | 32.2 (9.3) | 40.0 (4.6) | 22.4 (8.0) | 33.4 (6.2) | 33.3 (7.7) |
| MVPA score | 40.1 (28.1) | 45.1 (25.8) | 28.1 (28.7) | 32.9 (17.5) | 54.7 (31.9) |
| VO2peak (mL/kg/min) | 35.8 (7.7) | 37.5 (6.8) | 36.3 (8.5) | 32.6 (7.9) | 36.5 (7.4) |
| % of VO2peak at VT | 65.2 (15.2) | 65.7 (15.2) | 67.1 (15.1) | 67.0 (15.5) | 61.1 (15.8) |
| BMI | 22.7 (3.7) | 22.5 (3.7) | 21.4 (2.3) | 23.0 (4.3) | 24.1 (4.1) |

Table 4.2.
*Mean (SD) SAM ratings averaged across presentations according to slide content for the total sample and each personality group, and the summarized normative data for the IAPS slides employed.*

| | Normative | Total Sample | Low BIS | High BIS | Low BAS | High BAS |
|---|---|---|---|---|---|---|
| Unpleasant | | | | | | |
| Arousal | 6.5 (.4) | 6.1 (1.3) | 5.8 (1.5) | 6.3 (1.0) | 6.0 (1.5) | 6.2 (1.3) |
| Valence | 2.1 (.5) | 3.2 (.8) | 3.2 (.7) | 3.2 (.8) | 3.4 (.8) | 2.9 (.9) |
| Dominance | 3.1 (.4) | 3.6 (1.4) | 3.8 (1.7) | 2.9 (.9) | 3.6 (1.2) | 4.0 (.1) |
| Neutral | | | | | | |
| Arousal | 3.2 (.6) | 3.7 (1.1) | 3.5 (1.1) | 4.0 (1.3) | 3.9 (1.1) | 3.2 (.9) |
| Valence | 4.6 (.4) | 4.9 (.2) | 5.0 (.2) | 4.9 (.2) | 5.0 (.2) | 4.9 (.2) |
| Dominance | 5.6 (.6) | 4.6 (1.3) | 5.0 (1.3) | 4.5 (1.0) | 4.8 (1.3) | 4.2 (1.7) |
| Pleasant | | | | | | |
| Arousal | 5.9 (.8) | 5.5 (1.4) | 5.4 (1.4) | 5.8 (.9) | 5.2 (1.5) | 5.5 (1.6) |
| Valence | 7.4 (.4) | 6.4 (.8) | 6.5 (.5) | 6.3 (.7) | 6.2 (.5) | 6.6 (.9) |
| Dominance | 5.9 (.6) | 5.1 (1.2) | 5.2 (1.3) | 5.1 (.9) | 5.0 (1.1) | 5.1 (1.5) |

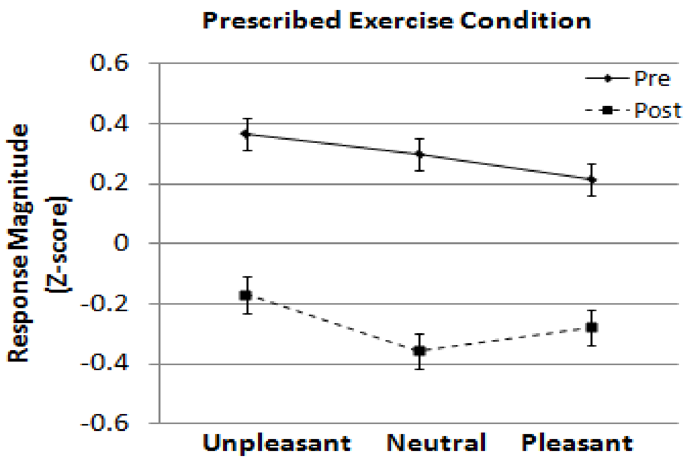
Table 4.3.
*Condition descriptions for the total sample as well as by personality group.*
VT: Ventilatory threshold; RPE: Ratings of perceived exertion.

| | Total Sample | Low BIS | High BIS | Low BAS | High BAS |
|---|---|---|---|---|---|
| Prescribed Exercise | | | | | |
| % VO2peak | 61.6 (7.0) | 58.3 (8.0) | 64.2 (5.5) | 64.5 (6.4) | 59.6 (6.0) |
| %VT | 101.1 (25.8) | 95.6 (26.9) | 101.8 (19.7) | 102.1 (21.7) | 104.8 (34.0) |
| RPE | 12.7 (1.3) | 12.6 (1.0) | 13.0 (1.2) | 12.8 (1.6) | 12.5 (1.5) |
| Self-Paced Exercise | | | | | |
| % VO2peak | 63.1 (6.8) | 63.6 (7.6) | 62.2 (5.0) | 62.3 (9.3) | 64.0 (5.7) |
| %VT | 103.7 (29.2) | 102.7 (20.3) | 98.7 (19.4) | 98.8 (24.5) | 114.1 (44.8) |
| RPE | 12.6 (1.1) | 12.3 (.7) | 12.9 (1.1) | 12.6 (1.4) | 12.8 (1.3) |
| Control Condition | | | | | |
| %VO2peak | 12.8 (4.5) | 11.5 (4.2) | 13.1 (4.6) | 15.3 (4.4) | 11.4 (4.0) |
| %VT | 21.2 (10.0) | 19.2 (10.7) | 21.1 (9.2) | 24.0 (7.7) | 20.9 (12.0) |
| RPE | 7.0 (.7) | 7.0 (.5) | 7.1 (.8) | 6.9 (.7) | 7.0 (.9) |

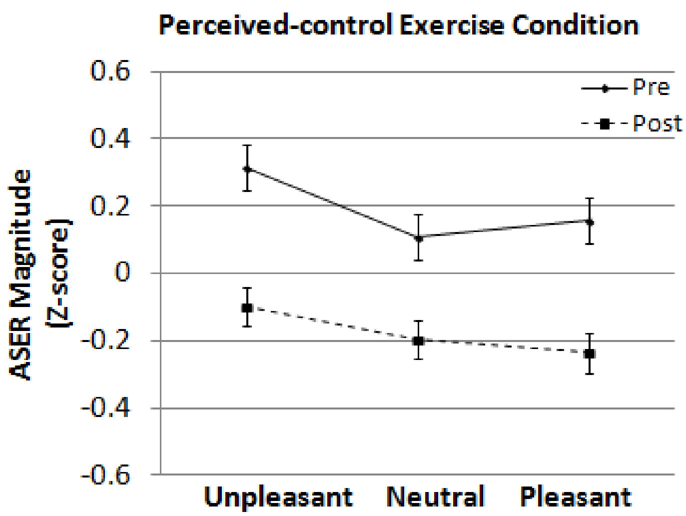
Table 4.4.
*Pearson's correlation for personality variables, physical activity level and fitness.*
**p*<.05; ***p*<.01; PA: physical activity

| | 1. | 2. | 3. | 4. | 5. |
|---|---|---|---|---|---|
| 1. BIS | 1.000 | | | | |
| 2. BAS | .076 | 1.000 | | | |
| 3. Extraversion | -.421** | .261* | 1.000 | | |
| 4. Stability | -.689** | -.005 | .466** | 1.000 | |
| 5. Moderate to vigorous PA | -.307* | .267* | .177 | .201 | 1.000 |
| 6. VO2peak (mL/kg/min) | -.076 | .112 | .189 | .062 | .379** |

Panel A.




Panel B.




Panel C.

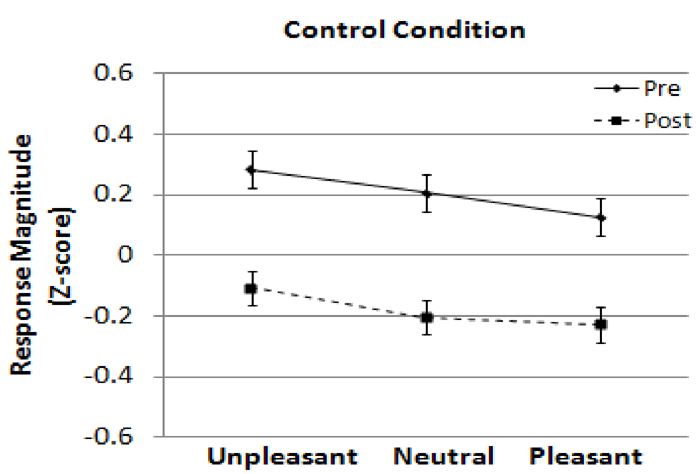



Figure 4.1.

*Effects for the valence by time ANOVAs for each condition for all 58 subjects.*
Error bars represent standard error for responses across presentations.

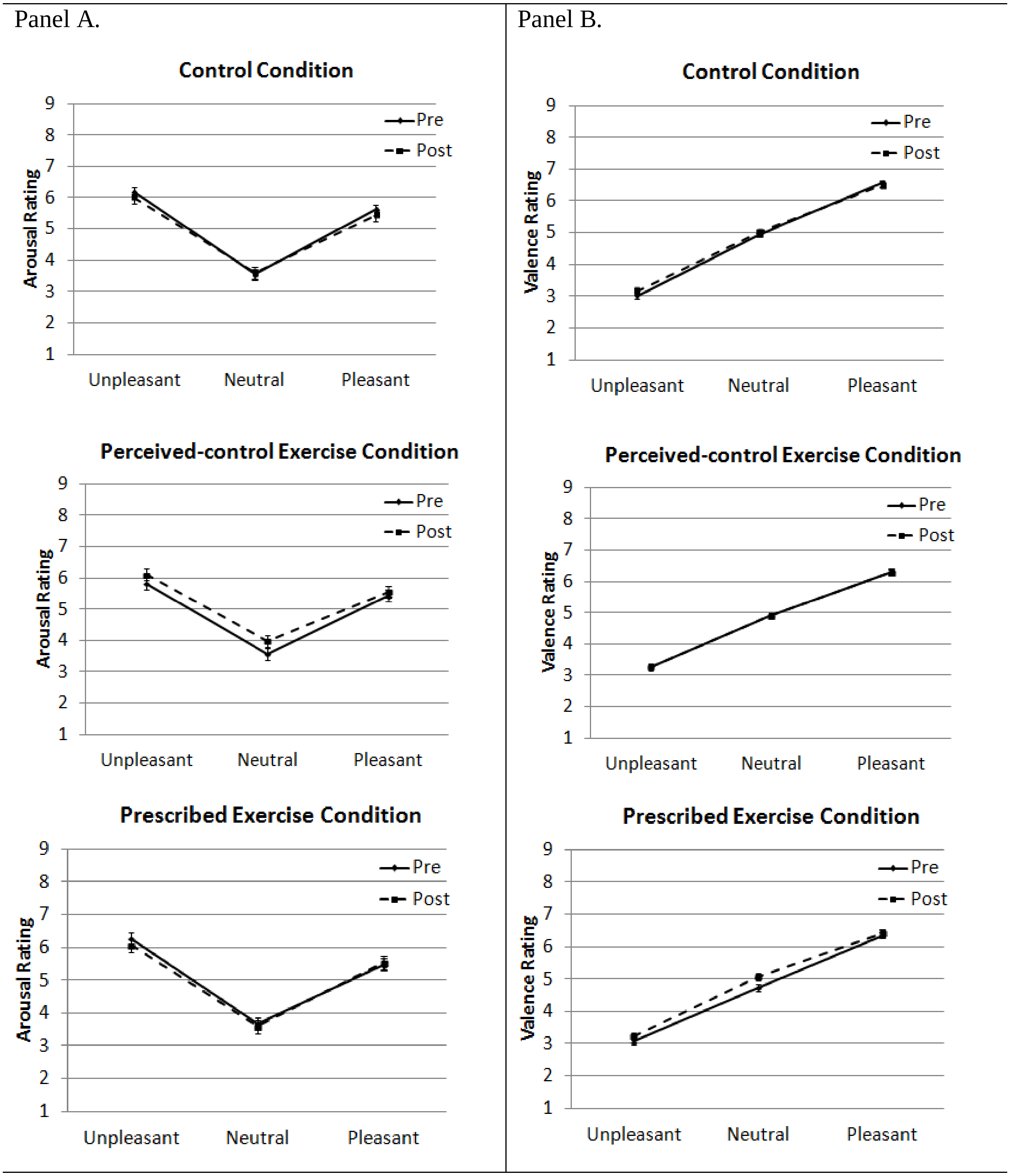



Figure 4.2.

*Mean (SD) ratings of arousal and valence in response to unpleasant, neutral, and pleasant slides before and after the three conditions for all 58 subjects.*

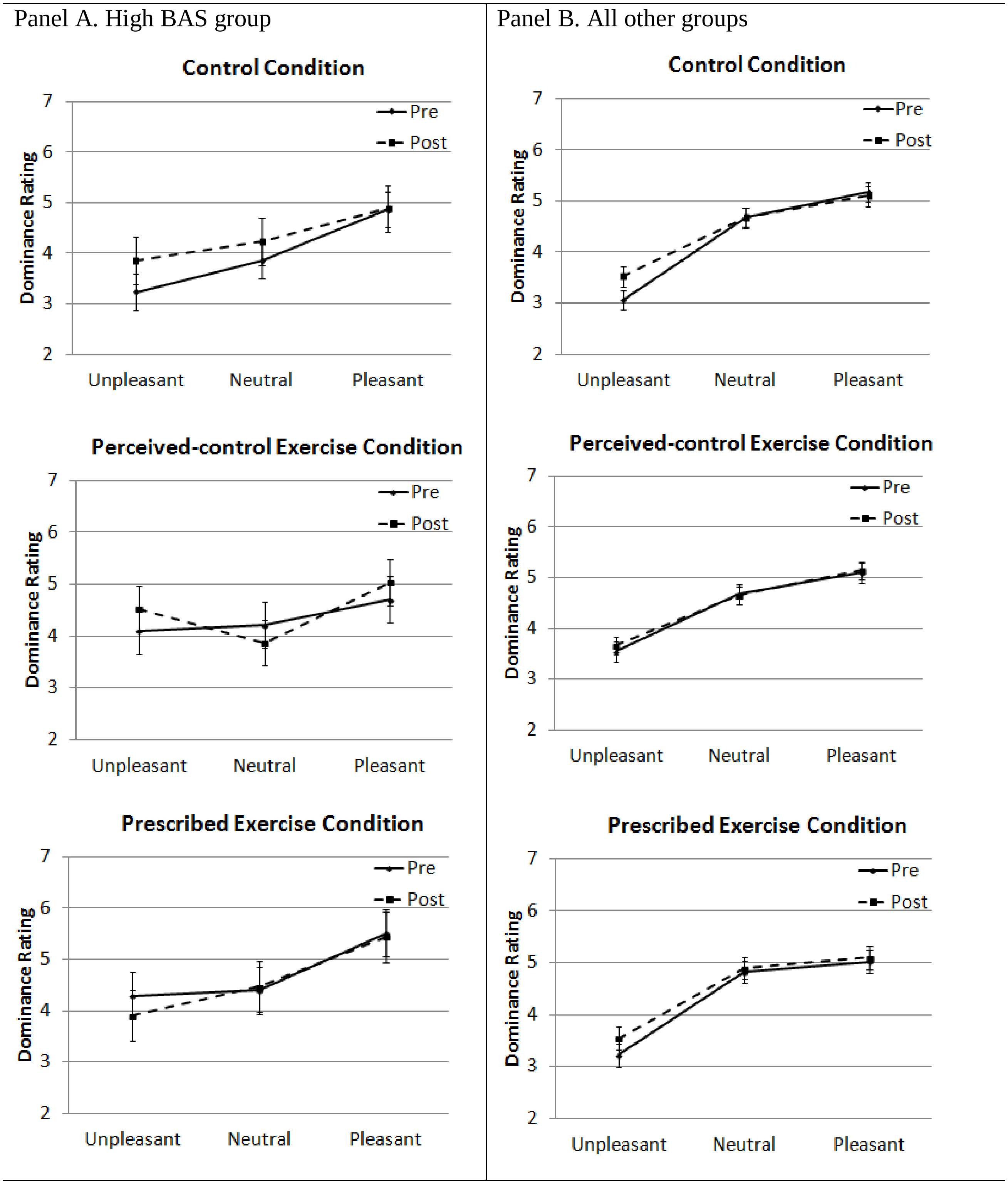



Figure 4.3.

*Mean (SD) dominance ratings in response to unpleasant, neutral, and pleasant slides before and after the three conditions for the high BAS group, and all other groups combined.*

# CHAPTER 5

## Summary

Physically active individuals report greater positive affect than those who are less active (Poole et al., 2011; Reed & Buck, 2009). The evidence supports a relationship between physical activity and affect, but there remains some inconsistency between studies (e.g. De Moor et al., 2008; Kawada et al., 2007). A clear understanding of the moderators of the physical activity/affect relationship is important for proper exercise prescription targeting mental health and physical activity adherence. A potential moderator that has received little attention in the literature is personality. Here, we reported on a quantitative synthesis of the literature on personality and physical activity, a structural regression model of the interrelationships between personality, physical activity and mental health, and a laboratory experiment testing the impact of individual differences in sensitivity to cues of reward or punishment on changes in emotional responding to aversive and appetitive stimuli after exercise with and without perceptions of control, or quiet rest.

We estimated the population correlation between Big-Five personality factors and physical activity and examined whether it varied according to sample characteristics and study features. Significant mean r was found for Extraversion ($r$ = .1076), Neuroticism ($r$ = -.0710), Conscientiousness ($r$ = .1037 and Openness ($r$ = .0344), but not Agreeableness ($r$ = -.0169). . Effects were heterogeneous and, except for Neuroticism, were moderated by characteristics of the sample or study features. Interactions influencing these relationships suggest that more complex moderation may be present in some cases, though more evidence is needed to appropriately assess this possibility. Analyses also support an age dependent relationship between physical activity and Agreeableness. Variation in the measurement and conceptualization of physical activity and personality limits our ability to more accurately describe their true relationships, and highlights the lack of a consistent research paradigm in these fields and the challenges presented for cross study comparisons.

The use of objective physical activity measures to capture frequency, duration and intensity, preferably in conjunction with a self-report of physical activity mode among studies exploring physical activity and personality is recommended, as are prospective study designs, so that we may more precisely conceptualize how personality influences the development of habitual physical activity. Detailed descriptions of samples and more work examining associations of lower order traits and physical activity are encouraged to facilitate a better understanding of physical activity as a behavioral domain that manifests personality differences as well as the application of personality theory by interventionists and clinicians seeking to increase physical activity.

We went on to examine the influence of personality on the association between mental health and physical activity measured by convergent self-reports and an accelerometer. Two samples of female undergraduates completed personality questionnaires and self-reports of physical activity. The second sample also completed a measure of mental health and wore an accelerometer for 7 days to objectively measure physical activity. Structural equation modeling was used to test competing models for the structural relationships between personality, physical activity, and mental health.

Results from this study indicate that the relationship between physical activity and mental health depends on personality, in agreement with previous reports suggesting that the observed relationship between mental health and self-reported physical activity is confounded with personality (De Moor et al., 2006; De Moor et al., 2008). However, when physical activity was measured objectively by an accelerometer, it interacted with personality to influence mental health. Specifically, the positive effect of physical activity was observed only among neurotic introverts, who are at higher risk for mental health problems, though a negative impact of physical activity on mental health was observable among stable introverts. BIS may be protective against inactivity among those reporting high Neuroticism.

Prediction of physical activity by personality depends on the method used to measure physical activity. Replication studies are recommended using objective measures of physical activity in population-based prospective cohorts or randomized controlled trials in clinical samples, to determine the extent to which personality modifies the effect of physical activity on mental health, or conversely the extent to which physical activity protects against mental health risk among high risk personalities, such as neurotic introverts.

Lastly, we used a mixed model repeated measures design to examine valence-modification of startle and subjective ratings of arousal, valence, and dominance in response to unpleasant, neutral, and pleasant slides before and after moderate intensity exercise with and without perceived control, or quiet rest among groups selected for high and low sensitivity to aversive or appetitive stimuli. Results were in agreement with cumulative evidence, and suggest that emotional responding is generally unchanged after exercise when compared to control conditions, regardless of individual differences in sensitivity to valenced stimuli.

Startle responses and subjective ratings of valence support the conclusion that exercise does not alter the appraisal of picture content as appetitive or aversive. Ratings of arousal for neutral photos were increased after the perceived-control condition, but not the prescribed exercise condition or quiet rest. We also reported a null effect of exercise on dominance ratings of emotional stimuli.

Results suggest a mediating role of perceived control in general arousal after exercise, however, interpretations regarding the role of perceived control during exercise, and its influence on affective responding are premature. Replication is recommended to support or refute these observations, as there is little available evidence regarding the role of BIS/BAS traits in the effect of exercise on affective responses to aversive and appetitive stimuli. More work is needed to determine the impact of cognitive factors, such as perceived control, that may interact with personality to modify the affective response to acute exercise. The use of a physiological or behavioral correlate of BIS/BAS in conjunction with psychometric measures could improve the accuracy of grouping criteria and reveal the expected modifying effect of personality on affective responses to exercise.

In conclusion, we provide mixed evidence for the moderating role of personality in psychological correlates and responses to physical activity and acute exercise. Though the results of our laboratory experiment are somewhat disappointing, there is reason to believe that our grouping criteria were insufficient to acquire a sample with the desired level of extremity in BIS and BAS functioning. Results from the meta-analysis and structural regression model are encouraging, and suggest a significant relationship between personality and habitual physical activity level, as well as a moderating role of personality on the relationship between physical activity and mental health. Effects between personality and physical activity are dependent on sample characteristics and study features, whereas observable moderation of the mental health/physical activity relationship may be dependent on physical activity measurement quality.

More work is needed using objective measures of physical activity as most of the literature on personality and physical activity reports the use of physical activity self-reports, and the relationship between mental health and physical activity is diminished with the use of subjective measures. Furthermore, results from our laboratory experiment suggest that cognitive factors may influence post-exercise change in affective responding, and work should be done to test this possibility. More work is needed to clarify observed heterogeneity in effects between personality and physical activity, and affective responses to acute exercise. Future studies should focus on the role of trait interactions in exercise effects on emotional responding and the relationship of physical activity with mental health. Overall, evidence supports a moderating role of personality in the relationship between physical activity and mental health outcomes, and the possibility of interactions between personality and cognitive factors influencing affective responding after acute exercise.

# REFERENCES

Aiken, Leona S, & West, Stephen G. (1991). *Multiple regression: Testing and interpreting interactions*: Sage.

Alonso, Jordi, Angermeyer, Matthias C, Bernert, S, Bruffaerts, Ronny, Brugha, TS, Bryson, H, . . . Gasquet, I. (2004). Sampling and methods of the European Study of the Epidemiology of Mental Disorders (ESEMeD) project. *Acta Psychiatrica Scandinavica, 109*(s420), 8-20.

American College of Sports Medicine. (1998). American Heart Association Joint Position Statement. Recommendations for cardiovascular screening, staffing, and emergency policies at health/fitness facilities. *Med Sci Sports Exerc, 30*, 1009-1018.

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders: fourth edition, text revision*. Washington, DC.

Andersen, Lise G, Groenvold, Mogens, Jørgensen, Torben, & Aadahl, Mette. (2010). Construct validity of a revised Physical Activity Scale and testing by cognitive interviewing. *Scandinavian journal of public health, 38*(7), 707-714.

Anderson, James C., & Gerbing, David W. (1988). Structural equation modeling in practice: A review and recommended two-step approach. *Psychological Bulletin, 103*(3), 411-423. doi: 10.1037/0033-2909.103.3.411

Armstrong, Timothy, & Bull, Fiona. (2006). Development of the World Health Organization Global Physical Activity Questionnaire (GPAQ). *Journal of Public Health, 14*(2), 66-70. doi: 10.1007/s10389-006-0024-x

Asmundson, GJ, Fetzner, MG, Deboer, LB, Powers, MB, Otto, MW, & Smits, JA. (2013). Let's get physical: a contemporary review of the anxiolytic effects of exercise for anxiety and its disorder. *Depression and Anxiety, 30*(4), 362-373.

Barnes, Robert T., Coombes, Stephen A., Armstrong, Nicole B., Higgins, Torrance J., & Janelle, Christopher M. (2010). Evaluating attentional and affective changes following an acute exercise bout using a modified dot-probe protocol. *Journal of Sports Sciences, 28*(10), 1065-1076.

Bartholomew, John B, Morrison, David, & Ciccolo, Joseph T. (2005). Effects of acute exercise on mood and well-being in patients with major depressive disorder. *Medicine and Science in Sports and Exercise, 37*(12), 2032.

Batson, C. Daniel, Shaw, Laura L., & Oleson, Kathryn C. (1992). Differentiating affect, mood, and emotion: toward functionally based conceptual distinctions. In Margaret S. Clark (Ed.), *Emotion* (pp. 294-326). Newbury Park, CA: SAGE Publications, Inc.

Bauman, Adrian, Bull, Fiona, Chey, Tien, Craig, CL, Ainsworth, B. E., Sallis, J. F., . . . The IPS Group. (2009). The International Prevalence Study on Physical Activity: results from 20 countries. *International Journal of Behavioral Nutrition & Physical Activity, 6*(21), xxx-xxx.

Bauman, Adrian, Sallis, James F, Dzewaltowski, David A, & Owen, Neville. (2002). Toward a better understanding of the influences on physical activity: the role of determinants, correlates, causal variables, mediators, moderators, and confounders. *American journal of preventive medicine, 23*(2), 5-14.

Beard, John R., Heathcote, Kathy, Brooks, Robert, Earnest, Arul, & Kelly, Brian. (2007). Predictors of mental disorders and their outcome in a community based cohort. *Social Psychiatry And Psychiatric Epidemiology, 42*(8), 623-630.

Berg, W. Keith, & Balaban, Marie T. (1999). Startle elicitation: stimulus parameters, recording techniques, and quantification. In Michael E. Dawson, Anne M. Schell & Andreas H. Böhmelt (Eds.), *Startle modification: implications for neuroscience, cognitive science, and clinical science*. Cambridge, UK: Cambridge University Press.

Berger, Bonnie G., & Motl, Robert W. (2000). Exercise and mood: A selective review and synthesis of research employing the profile of mood states. *Journal of Applied Sport Psychology, 12*(1), 69-92. doi: 10.1080/10413200008404214

Berkman, Elliot T., Lieberman, Matthew D., & Gable, Shelly L. (2009). BIS, BAS, and response conflict: Testing predictions of the revised reinforcement sensitivity theory. *Personality & Individual Differences, 46*(5/6), 586-591. doi: 10.1016/j.paid.2008.12.015

Blumenthal, Terry D. (2001). Extraversion, attention, and startle response reactivity. *Personality and Individual Differences, 31*(4), 495-503. doi: http://dx.doi.org/10.1016/S0191-8869(00)00153-7

Blumenthal, Terry D, Cuthbert, Bruce N, Filion, Diane L, Hackley, Steven, Lipp, Ottmar V, & Van Boxtel, Anton. (2005). Committee report: Guidelines for human startle eyeblink electromyographic studies. *Psychophysiology, 42*(1), 1-15.

Bogg, T, & Roberts, BW. (2004). Conscientiousness and Health-Related Behaviors: A Meta-Analysis of the Leading Behavioral Contributors to Mortality. *Psychological Bulletin, 130*(6), 887-919. doi: 10.1037/0033-2909.130.6.887

Bollen, Kenneth A. (1989). A new incremental fit index for general structural equation models. *Sociological Methods & Research, 17*(3), 303-316.

Booth, Michael. (2000). Assessment of physical activity: An international perspective. *Research Quarterly for Exercise and Sport, 71*(2), 114-120.

Borg, G. (1998). *Borg's Perceived Exertion and Pain Scales*. Champaign, IL: Human Kinetics.

Bouchard, C., Blair, SN, Church, TS, & et al. (2012). Adverse metabolic response to regular exercise: is it a rare or common occurrences? *PLoS One, 7*(5), e37887.

Bouchard, T. J., & McGue, Matt. (2003). Genetic and environmental influences on human psychological differences. *Journal of Neurobiology, 54*(1), 4-45. doi: 10.1002/neu.10160

Bradley, M. M., Codispoti, M., & Lang, P. J. (2006). A multi-process account of startle modulation during affective perception. *Psychophysiology, 43*(5), 486-497. doi: 10.1111/j.1469-8986.2006.00412.x

Bradley, M. M., Cuthbert, B. N., & Lang, P. J. (1996). Picture media and emotion: Effects of a sustained affective context. *Psychophysiology, 33*, 662-670.

Bradley, M. M., Cuthbert, B. N., & Lang, P. J. (1999). Affect and the startle reflex. In Michael E. Dawson, Anne M. Schell & Andreas H. Bohmelt (Eds.), *Startle modification: Implications for Neuroscience, Cognitice Science, and Clinical Science* (pp. 157-183). Cambridge, UK: Cambridge University Press.

Bradley, M. M., Cuthbert, Bruce N., & Lang, Peter J. (1993). Pictures as prepulse: Attention and emotion in startle modification. *Psychophysiology, 30*(5), 541-545.

Bradley, M. M., & Lang, P. J. (1994). Measuring emotion: The self-assessment manikin and the semantic differential. *Journal of Behavior Therapy and Experimental Psychology, 25*(1), 49-59.

Bray, MS, Hagberg, JM, Perusse, L, & et al. (2009). The human gene map for performance and health-related fitness phenotypes: the 2006-2007 update. *Medicine and Science in Sports and Exercise, 41*(1), 34-73.

Brenner, Sharon L., Beauchaine, Theodore P., & Sylvers, Patrick D. (2005). A comparison of psychophysiological and self-report measures of BAS and BIS activation. *Psychophysiology, 42*(1), 108-115.

Brown, Wendy J., Ford, Jessica H., Burton, Nicola W., Marshall, Alison L., & Dobson, Annette J. (2005). Prospective Study of Physical Activity and Depressive Symptoms in Middle-Aged Women. *American Journal of Preventive Medicine, 29*(4), 265-272. doi: 10.1016/j.amepre.2005.06.009

Bull, Fiona C., Maslin, Tahlia S., & Armstrong, Timothy. (2009). Global physical activity questionnaire (GPAQ): nine country reliability and validity study. *Journal Of Physical Activity & Health, 6*(6), 790-804.

Byrne, A., & Byrne, D. G. (1993). The effect of exercise on depression, anxiety and other mood states: A review. *Journal of Psychosomatic Research, 37*(6), 565-574. doi: 10.1016/0022-3999(93)90050-p

Cabanac, M., & Leblanc, J. (1983). Physiological conflict in humans: fatigue vs. cold discomfort. *American Journal of Physiology - Regulatory, Integrative and Comparative Physiology, 244*(5), R621-R628.

Campbell-Sills, Laura, Liverant, Gabrielle I., & Brown, Timothy A. (2004). Psychometric Evaluation of the Behavioral Inhibition/Behavioral Activation Scales in a Large Sample of Outpatients With Anxiety and Mood Disorders. *Psychological Assessment, 16*(3), 244-254. doi: 10.1037/1040-3590.16.3.244

Cardinal, Bradley J., Esters, Jacqueline, & Cardinal, Marita K. (1996). Evaluation of the revised Physical Activity Readiness Questionnaire in older adults. *Medicine & Science in Sports & Exercise, 28*(4), 468-472.

Carver, Charles S. (2001). Affect and the Functional Bases of Behavior: On the Dimensional Structure of Affective Experience. *Personality & Social Psychology Review (Lawrence Erlbaum Associates), 5*(4), 345-356.

Carver, Charles S., & Scheier, Michael F. (1990). Origins and functions of positive and negative affect: A control-process view. *Psychological Review, 97*(1), 19-35. doi: 10.1037/0033-295x.97.1.19

Carver, Charles S., & White, Teri L. (1994). Behavioral inhibition, behavioral activation, and affective responses to impending reward and punishment: The BIS/BAS Scales. *Journal of Personality and Social Psychology, 67*(2), 319-333. doi: 10.1037/0022-3514.67.2.319

Caseras, X., Àvila, C., & Torrubia, R. (2003). The measurement of individual differences in Behavioural Inhibition and Behavioural Activation Systems: a comparison of personality scales. *Personality and Individual Differences, 34*(6), 999-1013. doi: 10.1016/s0191-8869(02)00084-3

Caspersen, Carl J., Pereira, Mark A. , & Curran, Katy M. (2000). Changes in physical activity patterns in the United States, by sex and cross-sectional age. *Medicine and Science in Sports and Exercise, 32*(9), 1601-1609.

Caspersen, Carl J., Powell, Kenneth E., & Christenson, Gregory M. . (1985). Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public Health Reports, 100*(2), 126.

Cattell, Raymond B. "Confirmation and clarification of primary personality factors." Psychometrika 12.3 (1947): 197-220. (1947). Confirmation and clarification of primary personality factors. *Psychometrika, 12*(3), 197-220.

Centers for Disease Control and Prevention. (2007). Revalence of regular physical activity among adults -- United States 2001 and 2005 *Morbidity and Mortality Weekly Report* (Vol. 56, pp. 1209-1212).

Chen, Michael J., Fan, Xitao, & Moe, Sondra T. (2002). Criterion-related validity of the Borg ratings of perceived exertion scale in healthy individuals: a meta-analysis. *Journal of Sports Sciences, 20*(11), 873-899.

Chu-Hsin, Huang, Li-Yueh, Lee, & Man-Ling, Chang. (2007). THE INFLUENCES OF PERSONALITY AND MOTIVATION ON EXERCISE PARTICIPATION AND QUALITY OF LIFE. *Social Behavior & Personality: An International Journal, 35*(9), 1189-1209.

Conn, Vicki S. (2010). Anxiety Outcomes After Physical Activity interventions Meta-Analysis Findings. *Nursing Research, 59*(3), 224-231.

Cooper, Andrew, Gomez, Rapson, & Aucote, Helen. (2007). The Behavioural Inhibition System and Behavioural Approach System (BIS/BAS) Scales: Measurement and structural invariance across adults and adolescents. *Personality & Individual Differences, 43*(2), 295-305. doi: 10.1016/j.paid.2006.11.023

Corr, Philip J. (2001). Testing problems in J. A. Gray's personality theory: a commentary on Matthews and Gilliland (1999). *Personality & Individual Differences, 30*, 333-352.

Corr, Philip J. (2002). J. A. Gray's reinforcement sensitivity theory: tests of the joint subsystems hypothesis of anxiety and impulsivity. *Personality and Individual Differences, 33*(4), 511-532. doi: 10.1016/s0191-8869(01)00170-2

Corr, Philip J., Kumari, Veena, Wilson, Glenn D., Checkley, Stuart, & Gray, Jeffrey A. (1997). Harm avoidance and affective modulaion of the startle reflex:  A replication. *Personality & Individual Differences, 22*(4), 591-593.

Corr, Philip J., Wilson, Glenn D., Fotiadou, Maria, Kumari, Veena, Gray, Nicola S., Checkley, Stuart, & Gray, Jeffrey A. (1995). Personality and affective modulation of the startle reflex. *Personality and Individual Differences, 19*(4), 543-553. doi: http://dx.doi.org/10.1016/0191-8869(95)00059-F

Costa, Paul, Jr., & McCrae, R. R. (1992). *Revised NEO Personality Inventory (NEO-PI-R) and NEO Five-Factor Inventory (NEO-FFI): Professional Manual*. Odessa, FL: Psycholoigcal Assessment Reseources, Inc.

Costa, Paul, Jr., Terracciano, Antonio, & McCrae, Robert R. (2001). Gender differences in personality traits across cultures: Robust and surprising findings. *Journal of Personality and Social Psychology, 81*(2), 322-331. doi: 10.1037/0022-3514.81.2.322

Courneya, Kerry S., Bobick, Todd M., & Schinke, Robert J. (1999). Does the Theory of Planned Behavior Mediate the Relation Between Personality and Exercise Behavior? *Basic & Applied Social Psychology, 21*(4), 317-324.

Courneya, Kerry S., Friedenreich, Christine M., Sela, Rami A., Quinney, H. Arthur, & Rhodes, Ryan E. (2002). Correlates of adherence and contamination in a randomized controlled trial of exercise in cancer survivors: an application of the theory of planned behavior and the five factor model of personality. *Annals Of Behavioral Medicine: A Publication Of The Society Of Behavioral Medicine, 24*(4), 257-268.

Crabbe, James B., Smith, Carson J., & Dishman, Rod K. (2007). Emotional and electroencephalographic responses during affective picture viewing after exercise. *Physiology and Behavior, 90*, 394-404.

Craft, L. L., & Landers, D. M. (1998). The effect of exercise on clinical depression and depression resulting from mental illness: A meta-analysis. *Journal of Sport and Exercise Psychology, 20*(4), 339-357.

Craig, CL, Marshall, AL, Sjöström, M, Bauman, AE, Booth, ML, Ainsworth, BE, . . . Sallis, JF. (2003). International Physical Activity Questionnaire (IPAQ): 12-country reliability and validity. *Med Sci Sports Exerc, 35*, 1381-1395.

Craig, CL, Marshall, Alison L., Sjostrom, M., Bauman, Adrian, Booth, Michael, Ainsworth, B. E., . . . Pekka. (2003). International Physical Activity Questionnaire: 12-country reliability and validity. *Medicine & Science in Sports & Exercise, 35*(8), 1381-1395.

Cuthbert, B. N., Bradley, M. M., & Lang, P. J. (1996). Probing picture perception: Activation and emotion. *Pscyhophysiology, 33*, 103-111.

Davis, Caroline, & Fox, John. (1993). Excessive exercise and weight preoccupation in women. *Addictive Behaviors, 18*(2), 201-211. doi: 10.1016/0306-4603(93)90050-j

Davis, Caroline, Fox, John, Brewer, Howard, & Ratusny, Dorothy. (1995). Motivations to exercise as a function of personality characteristics, age, and gender. *Personality and Individual Differences, 19*(2), 165-174. doi: 10.1016/0191-8869(95)00030-a

De Moor, M. H. M., Beem, A. L., Stubbe, J. H., Boomsma, D. I., & De Geus, E. J. C. (2006). Regular exercise, anxiety, depression and personality: A population-based study. *Preventive Medicine, 42*(4), 273-279. doi: 10.1016/j.ypmed.2005.12.002

De Moor, M. H. M., Boomsma, D. I., Stubbe, J. H., Willemsen, G., & de Geus, E. J. C. (2008). Testing Causality in the Association Between Regular Exercise and Symptoms of Anxiety and Depression. *Arch Gen Psychiatry, 65*(8), 897-905. doi: 10.1001/archpsyc.65.8.897

Diener, Ed. (2000). Subjective well-being: The science of happiness and a proposal for a national index. *American Psychologist, 55*(1), 34-43. doi: 10.1037/0003-066X.55.1.34

Digman, J. M. (1989). Five robust trait dimensions: development, stability, and utility. *Journal Of Personality, 57*(2), 195-214.

Dishman, R. K. (2008). Gene-Physical Activity Interactions in the Etiology of Obesity: Behavioral Considerations. *Obesity (19307381), 16*, S60-S65.

Dishman, R. K., Rooks, C. R., Thom, N. J., Motl, R. W., & Nigg, C. R. (2010). Meeting U.S. Healthy People 2010 Levels of Physical Activity: Agreement of 2 Measures Across 2 Years. *Annals of Epidemiology, 20*(7), 511-523. doi: 10.1016/j.annepidem.2010.04.004

Dishman, R.K., Sui, X, Church, TS, Hand, GA, Trivedi, MH, & Blair, SN. (2012). Decline in cardiorespiratory fitness and odds of incident depression. *American Journal of Preventive Medicine, 43*(4), 361-368.

Dunn, A. L., Trivedi, M.H., & O'Neal, H.A. (2001). Physical activity dose-response effecs on outcomes of depression and anxiety. *Medicine & Science in Sports & Exercise, 33(Supplement)*, S587-S597.

Dyrstad, SM, Hansen, BH, Holme, IM, & Anderssen, SA. (2014). Comparison of Self-reported versus Accelerometer-Measured Physcial Activity. *Medicine and Science in Sports and Exercise, 46*(1), 99-106. doi: 10.1249/MSS.0b013e3182a0595f

Egger, Matthias, Smith, George Davey, Schneider, Martin, & Minder, Christoph. (1997). Bias in Meta-Analysis Detected by a Simple, Graphical Test. *BMJ: British Medical Journal, 315*(7109), 629-634. doi: 10.2307/25175671

Ekkekakis, P., Parfitt, Gaynor, & Petruzzello, Steven J. (2011). The pleasure and displeasure people feel when they exercise at different intensities: decennial update and progress towards a tripartite rationale for exercise intensity prescription. *Sports Medicine (Auckland, N.Z.), 41*(8), 641-671. doi: 10.2165/11590680-000000000-00000

Ekkekakis, P., & Petruzzello, S. J. (1999). Acute aerobic exercise and affect: current status, problems and prospects regarding dose-response. / Exercice aerobie intense et affect: etat des recherches, problemes et perpectives concernant la relation entre la dose et ses effets. *Sports Medicine, 28*(5), 337-374.

Eysenck, Hans J. (1967). *The biological basis of personality*. Springfield, IL: Charles C. Thomas.

Eysenck, Hans J. (1970). *The structure of human personality*. London: Methuen.

Eysenck, Hans J. (1991). Dimensions of personality: 16, 5 or 3?—Criteria for a taxonomic paradigm. *Personality and Individual Differences, 12*(8), 773-790. doi: http://dx.doi.org/10.1016/0191-8869(91)90144-Z

Eysenck, Hans J, & Eysenck, M. W. (1985). *Personality and individual differences*. New York: Plenum Press.

Eysenck, Hans J, Nias, D. K. B., & Cox, D. N. (1982). Sport and personality. *Advances in Behaviour Research & Therapy, 4*(1), 1-56.

Freixanet, Montserrat Goma I. (1991). Personality profile of subjects engaged in high physical risk sports. *Personality and Individual Differences, 12*(10), 1087-1093. doi: 10.1016/0191-8869(91)90038-d

Fridlund, Alan J., & Cacioppo, John T. (1986). Guidelines for Human Electromyographic Research. *Psychophysiology, 23*(5), 567-580.

Gable, Shelly L., Reis, Harry T., & Elliot, Andrew J. (2000). Behavioral Activation and Inhibition in Everyday Life. *Journal of Personality & Social Psychology, 78*(6), 1135-1149. doi: 10.1037//0022-3514.78.6.1135

Giacobbi, Peter R., Hausenblas, Heather A., & Frye, Nancy. (2005). A naturalistic assessment of the relationship between personality, daily life events, leisure-time exercise, and mood. *Psychology of Sport and Exercise, 6*(1), 67-81. doi: 10.1016/j.psychsport.2003.10.009

Ginis, KA Martin, & Latimer, AE. (2007). The effects of single bouts of body-weight supported treadmill training on the feeling states of people with spinal cord injury. *Spinal cord, 45*(1), 112-115.

Godin, G., & Shephard, R. J. (1985). A simple method to assess exercise behavior in the community. *Can J Appl Sport Sci, 10*, 141-146.

Goldberg, Lewis R. (1993). The structure of phenotypic personality traits. *American Psychologist, 48*(1), 26-34. doi: 10.1037/0003-066X.48.1.26

Goldberg, Lewis R. (1999). A broad-bandwidth, public-domain, personality inventory measuring the lower-level facets of several five-factor models. In I. Mervielde, I. Deary, F. De Fruyt & F. Ostendorf (Eds.), *Personality Psychology in Europe* (Vol. 7, pp. 7-28). Tilburg, The Netherlands: Tilburg University Press.

Goldberg, Lewis R., Johnson, John A., Eber, Herbert W., Hogan, Robert, Ashton, Michael C., Cloninger, C. Robert, & Gough, Harrison G. (2006). The international personality item pool and the future of public-domain personality measures. *Journal of Research in Personality, 40*(1), 84-96. doi: 10.1016/j.jrp.2005.08.007

Gonzalez, Jose J, Hynd, George W, & Martin, Roy P. (1994). Neuropsychology of Temperament. In P. A. Vernon (Ed.), *The Neuropsychology of Individual Differences*. San Diego, CA: Academic Press, Inc.

Gosling, Samuel D., & John, Oliver P. (1999). Personality Dimensions in Nonhuman Animals: A Cross-Species Review. *Current Directions in Psychological Science (Wiley-Blackwell), 8*(3), 69.

Gray, J. A. (1970). The psychophysiological basis of introversion-Extraversion. *Behavior Research and Therapy, 8*, 249-266.

Gray, J. A. (1981). A critique of Eysenck's theory of personality. In H. J. Eysenck (Ed.), *A model for personality* (pp. 246-276). Berlin: Springer.

Gray, J. A. (1982). *The neuropsychology of anxiety: An enquiry into the functions of the septo-hippocampal system*. New York: Oxford University Press.

Gray, J. A. (1987). Perspectives on anxiety and impulsivity: A commentary. *Journal of Research in Personality, 21*(4), 493-509. doi: Doi: 10.1016/0092-6566(87)90036-5

Gray, J. A. (1991). The Neuropsychology of Temperament. In Jan Strelau & Alois Angleitner (Eds.), *Explorations in Temperament* (pp. 105-128). New York: Plenum Press.

Gray, J. A., & McNaughton, N. (2000). *The neuropsychology of anxiety: An enquiry into the funtions of the septo-hippocampal system* (2nd ed. ed.). Oxford: Oxford University Press.

Gray, J. A., Owen, S., Davis, N. , & Tsaltas, E. (1983). Psychological and physiological relations between anxiety and impulsivity. In Marvin Zuckerman (Ed.), *The Biological Bases of Sensation Seeking, Impulsivity, and Anxiety* (pp. 189-217). Hillsdale: Earlbaum.

Hall, E. E., Ekkekakis, P., & Petruzzello, S. J. (2005). Is the relationship of RPE to psychological factors intensity-dependent? *Medicine and Science in Sports and Exercise, 337*(8), 1365-1373.

Harmon-Jones, Eddie, & Allen, John J. B. (1997). Behavioral activation sensitivity and resting frontal EEG asymmetry: Covariation of putative indicators related to risk for mood disorders. *Journal of Abnormal Psychology, 106*(1), 159-163. doi: 10.1037/0021-843X.106.1.159

Hawk, Larry W., & Kowmas, Audrey D. (2003). Affective modulation and prepulse inhibition of startle among undergraduates high and low in behavioral inhibition and approach. *Psychophysiology, 40*(1), 131-138. doi: 10.1111/1469-8986.00013

Heath, GW, Parra, DC, Sarmiento, OL, Andersen, LB, Owen, N, Goenka, S, . . . Brownson, RC. (2012). Evidence-based intervention in physical activity: lessons from around the world. *Lancet, 380*(9838), 272-281.

Heesch, Kristiann C, Burton, Nicola W, & Brown, Wendy J. (2011). Concurrent and prospective associations between physical activity, walking and mental health in older women. *Journal of epidemiology and community health, 65*(9), 807-813.

Hemingway, Harry, Stafford, Mai, Stansfeld, Stephen, Shipley, Martin, & Marmot, Michael. (1997). Is the SF-36 a Valid Measure of Change in Population Health? Results from the Whitehall II Study. *BMJ: British Medical Journal, 315*(7118), 1273-1279.

Heponiemi, Tarja, Keltikangas-Jävinen, Liisa, Kettunen, Joni, Puttonen, Sampsa, & Ravaja, Niklas. (2004). BIS–BAS sensitivity and cardiac autonomic stress profiles. *Psychophysiology, 41*(1), 37-45.

Herring, M. P. (2010). *Effects of exercise training on generalized anxiety disorder and medical patients.* (Doctor of Philosophy Dissertation), University of Georgia, Athens, Georgia.

Herring, M. P., Jacob, ML, Suveg, C, Dishman, RK, & O'Connor, PJ. (2012). Feasibility of exercise training for the short-term treatment of generalized anxiety disorder: a randomized controlled trial. *Psychotherapy and Psychosomoatics, 81*(1), 21-28. doi: 10.1159/000327898

Herring, M. P., O'Connor, PJ, & Dishman, RK. (2010). The Effect of Exercise Training on Anxiety Symptoms Among Patients: A Systematic Review. *Arch Intern Med, 170*(4), 321-331. doi: 10.1001/archinternmed.2009.530

Herring, M. P., O’Connor, P. J., & Dishman, R. K. (2010). The effect of exercise training on anxiety symptoms among patients: A systematic review. *Archives of Internal Medicine, 170*(4), 321-331. doi: 10.1001/archinternmed.2009.530

Herring, M. P., Puetz, Timothy W, O’Connor, Patrick J, & Dishman, Rodney K. (2012). Effect of exercise training on depressive symptoms among patients with a chronic illness: a systematic review and meta-analysis of randomized controlled trials. *Archives of internal medicine, 172*(2), 101-111.

Heubeck, Bernd G., Wilkinson, Ross B., & Cologon, John. (1998). A second look at Carver and White's (1994) BIS/BAS scales. *Personality and Individual Differences, 25*(4), 785-800. doi: Doi: 10.1016/s0191-8869(98)00124-x

Higgins, Julian P. T., Simon, G. Thompson, Deeks, Jonathan J., & Altman, Douglas G. (2003). Measuring Inconsistency In Meta-Analyses. *BMJ: British Medical Journal, 327*(7414), 557-560. doi: 10.2307/25455439

Hofstee, Willem K, De Raad, Boele, & Goldberg, Lewis R. (1992). Integration of the Big Five and circumplex approaches to trait structure. *Journal of Personality and Social Psychology, 63*(1), 146.

Hu, Li-tze, & Bentler, Peter M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal, 6*(1), 1-55.

Hunter, John E., & Schmidt, Frank L. (1990). Dichotomization of continuous variables: The implications for meta-analysis. *Journal of Applied Psychology, 75*(3), 334-349. doi: 10.1037/0021-9010.75.3.334

Hunter, John E., & Schmidt, Frank L. (2004). *Methods of meta-analysis: Correcting error and bias in research findings* (2nd ed.): Sage.

Hunter, John E., Schmidt, Frank L., & Le, Huy. (2006). Implications of direct and indirect range restriction for meta-analysis methods and findings. *Journal of Applied Psychology, 91*(3), 594-612. doi: 10.1037/0021-9010.91.3.594

IBM. (2010). IBM SPSS Statistics for Windows.

Jaccard, James, & Wan, Choi K. (1995). Measurement error in the analysis of interaction effects between continuous predictors using multiple regression: Multiple indicator and structural equation approaches. *Psychological Bulletin, 117*(2), 348-357. doi: 10.1037/0033-2909.117.2.348

Jackson, Chris J., & Smillie, Luke D. (2004). Appetitive motivation predicts the majority of personality and an ability measure: A comparison of BAS measures and a re-evaluation of the importance of RST. *Personality and Individual Differences, 36*(7), 1627-1636. doi: 10.1016/j.paid.2003.06.010

Jacobs, D. R. Jr., Ainsworth, B. E., Hartman, T. J., & Leon, A.S. (1993). A simultaneous evaluation of 10 commonly used physical activity questionnaires. *Medicine & Science in Sports & Exercise, 25*, 81-91.

Jang, K. L., Livesley, W. J., & Vernon, P. A. (1996). Heritability of the big five personality dimensions and their facets: a twin study. *Journal Of Personality, 64*(3), r577-591.

John, Oliver P., & Srivastava, Sanjay. (1999). The Big Five Trait Taxonomy: History, Measurement, and Theoretical Perspecives. In Lawrence A. Pervin & Oliver P. John (Eds.), *Handbook of Personality: Theory and Research* (2nd ed.). New York: The Guilford Press.

Jonsdottir, IH, Rodjer, L, Hadzibarjramovic, E, Borjesson, M, & Ahlborg, G. (2010). A prospective study of leisure-time physical activity and mental health in Swedish health care workers and social insureance officers. *Preventive Medicine, 51*(5), 373-377.

Jorm, A. F., Christensen, H., Henderson, A. S., Jacomb, P. A., Korten, A. E., & Rodgers, B. (1999). Using the BIS/BAS scales to measure behavioural inhibition and behavioural activation: Factor structure, validity and norms in a large community sample. *Personality and Individual Differences, 26*(1), 49-58. doi: Doi: 10.1016/s0191-8869(98)00143-3

Kawada, Tomoyuki, Katsumata, Masao, Suzuki, Hiroko, & Shimizu, Takako. (2007). Actigraphic predictors of the depressive state in students with no psychiatric disorders. *Journal of Affective Disorders, 98*(1-2), 117-120. doi: 10.1016/j.jad.2006.07.004

Keiser, H.N., & Ross, S.R. (2011). Carver and Whites' BIS/FFFS/BAS scales and domains and facets of the Five Factor Model of personality. *Personality & Individual Differences, 51*, 39-44.

Kessler, R.C., Andrews, G., & Colpe. (2002). Short screening scales to moitor population prevalences and trends in non-specific psychological distress. *Psychological Medicine, 32*, 959-976.

Kirkcaldy, Bruce, & Furnam, Adrian. (1991). Extraversion, Neuroticism, Psychoticism and Recreational Choice. *Personality & Individual Differences, 12*(7), 737-745.

Kopp, Martin, Steinlechner, Maria, Ruedl, Gerhard, Ledochowski, Larissa, Rumpold, Gerhard, & Taylor, Adrian H. (2012). Acute effects of brisk walking on affect and psychological well-being in individuals with type 2 diabetes. *Diabetes research and clinical practice, 95*(1), 25-29.

Kriemler, S, Meyer, U, Martin, E, va Sluiis, EM, Andersen, LB, & Martin, BW. (2011). Effect of school-based interventions on physical activity and fitness in children and adolescents: a review of review and systematic update. *British Journal of Sports Medicine, 45*, 923-930.

Kumari, Veena, Corr, Philip J., Wilson, Glenn D., Kaviani, Hossein, Thornton, Jasper C., Checkley, Stuart A., & Gray, Jeffrey A. (1996). Personality and modulation of the startle reflex by emotionally-toned filmclips. *Personality and Individual Differences, 21*(6), 1029-1041. doi: 10.1016/s0191-8869(96)00157-2

Kwan, Bethany M., & Bryan, Angela. (2010). In-task and post-task affective response to exercise: Translating exercise intentions into behaviour. *British Journal of Health Psychology, 15*(1), 115-131.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1990). Emotion, attention, and the startle reflex. *Psychological review, 97*(3), 377.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (2008). International affective picture system (IAPS): Affective ratins of pictures and instruction manual. Technical Report A-8. Gainesville, FL: University of Florida.

Lang, P. J., Bradley, Margaret M., & Cuthbert, Bruce N. (1990). Emotion, attention, and the startle reflex. *Psychological Review, 97*(3), 377-395. doi: 10.1037/0033-295x.97.3.377

LaRowe, Steven D., Patrick, Christopher J., Curtin, John J., & Kline, John P. (2006). Personality correlates of startle habituation. *Biological Psychology, 72*(3), 257-264. doi: http://dx.doi.org/10.1016/j.biopsycho.2005.11.008

Larson, Christine L. (2000). Temporal stability of the emotion-modulated startle response. *Psychophysiology, 37*(1), 92-101.

Leone, Luigi, Perugini, Marco, Bagozzi, Richard P., Pierro, Antonio, & Mannetti, Lucia. (2001). Construct validity and generalizability of the Carver–White behavioural inhibition system/behavioural activation system scales. *European Journal of Personality, 15*(5), 373-390. doi: 10.1002/per.415

Lewin, Kurt. (1935). *A Dynamic Theory of Personality*. New York: McGraw-Hill Book Company, Inc.

Lochbaum, M. R., Litchfield, K., Podlog, L., & Lutz, R. (2013). Extraversion, emotional instability, and self-reported exercise: The mediating effects of approach-avoidance achievement goals. *Journal of Sport and Health Science, 2*, 176-183. doi: http://dx.doi.org/10.1016/j.jshs.2012.08.002

Lochbaum, M. R., & Lutz, Rafer. (2005). Exercise Enjoyment and Psychological Response to Acute Exercise: The Role of Personality and Goal Cognitions. *Individual Differences Research, 3*(3), 153-161.

Lochbaum, M. R., Rhodes, R. E., Stevenson, S. J., Surles, J., Stevens, T., & Wang, C. K. J. (2010). Does gender moderate the exercising personality? An examination of continuous and stage-based exercise. *Psychology, Health & Medicine, 15*(1), 50-60. doi: 10.1080/13548500903443449

Long, B. C., & Van Stavel, R. (1995). Effects of exercise training on anxiety: a meta-analysis. / Effets de l'entrainement sur l'anxiete - une meta-analyse. *Journal of Applied Sport Psychology, 7*(2), 167-189.

Loy, Bryan D, O'Connor, Patrick J, & Dishman, Rodney K. (2013). The effect of a single bout of exercise on energy and fatigue states: a systematic review and meta-analysis. *Fatigue: Biomedicine, Health & Behavior, 1*(4), 223-242.

Martin, Corby K, Church, Timothy S, Thompson, Angela M, Earnest, Conrad P, & Blair, Steven N. (2009). Exercise dose and quality of life: a randomized controlled trial. *Archives of Internal Medicine, 169*(3), 269.

Martin, Peter, Bishop, Alex, Poon, Leonard, & Johnson, Mary Ann. (2006). Influence of personality and health behaviors on fatigue in late and very late life. *The Journals Of Gerontology. Series B, Psychological Sciences And Social Sciences, 61*(3), P161-P166.

McClain, James J., Hart, Teresa L., Getz, Renee S., & Tudor-Locke, Catrine. (2010). Convergent Validity of 3 Low Cost Motion Sensors With the ActiGraph Accelerometer. *Journal of Physical Activity & Health, 7*(5), 662-670.

McCrae, Robert R., & Costa, Jr, P.T. (1999). A Five-Factor Theory of Personality. In Lawrence A. Pervin & Oliver P. John (Eds.), *Handbook of Personality: Theory and Research* (2nd ed.). New York: The Guilford Press.

McCrae, Robert R., & Costa, Paul T. (1987). Validation of the five-factor model of personality across instruments and observers. *Journal of Personality and Social Psychology, 52*(1), 81-90. doi: 10.1037/0022-3514.52.1.81

McCrae, Robert R., Costa, Paul T., Jr., Ostendorf, Fritz, Angleitner, Alois, Hřebíčková, Martina, Avia, Maria D., . . . Smith, Peter B. (2000). Nature over nurture: Temperament, personality, and life span development. *Journal of Personality and Social Psychology, 78*(1), 173-186. doi: 10.1037/0022-3514.78.1.173

McHorney, Colleen A., Ware, John E., Jr., & Raczek, Anastasia E. (1993). The MOS 36-Item Short-Form Health Survey (SF-36): II. Psychometric and Clinical Tests of Validity in Measuring Physical and Mental Health Constructs. *Medical Care, 31*(3), 247-263.

McMinn, David, Rowe, David A., Stark, Michelle, & Nicol, Louise. (2010). Validity of the New Lifestyles NL-1000 Accelerometer for Measuring Time Spent in Moderate-to-Vigorous Physical Activity in School Settings. *Measurement in Physical Education and Exercise Science, 14*(2), 67-78. doi: 10.1080/10913671003715516

McNaughton, Neil, & Corr, Philip J. (2004). A two-dimensional neuropsychology of defense: fear/anxiety and defensive distance. *Neuroscience & Biobehavioral Reviews, 28*(3), 285-305. doi: 10.1016/j.neubiorev.2004.03.005

Metcalf, B, Henley, W, & Wilkig, T. (2012). Effectiveness of intervention on physical activity of hcildren:  systmativ review and meta-analysis of controlled trials with objectively measured outcomes (EarlyBird 54). *British Medical Journal, 345*, e5888. doi: 10.1137/bmj.e5888

Michie, Susan, Abraham, Charles, Whittington, Craig, McAteer, John, & Gupta, Sunjai. (2009). Effective techniques in healthy eating and physical activity interventions: a meta-regression. *Health Psychology, 28*(6), 690.

Miller, D. J., Freedson, P.S. , & Kline, G. M. (1994). Comparison of activity levels using Caltrac accelerometer and five questionnaires. *Medicine & Science in Sports & Exercise, 26*, 376-382.

Mitchell, John T., Kimbrel, Nathan A., Hundt, Natalie E., Cobb, Amanda R., Nelson-Gray, Rosemery O., & Lootens, Christopher M. (2007). An analysis of reinforcement sensitivity theory and the five-factor model. *Europena Journal of Personality, 21*, 869-887.

Moher, David, Liberati, Alessandro, Tetzlaff, Jennifer, & Altman, Douglas G. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Annals Of Internal Medicine, 151*(4), 264.

Morgan, William P. (1985). Affective beneficence of vigorous physical activity. *Medicine and Science in Sports and Exercise, 17*(1), 94-100.

Moses, Jennifer, Steptoe, Andrew, Mathews, Andrew, & Edwards, Sara. (1989). The effects of exercise training on mental well-being in the normal population: A controlled trial. *Journal of Psychosomatic Research, 33*(1), 47-61. doi: 10.1016/0022-3999(89)90105-0

Motl, Robert W., McAuley, Edward, & DiStefano, Christine. (2005). Is social desirability associated with self-reported physical activity? *Preventive Medicine, 40*(6), 735-739. doi: http://dx.doi.org/10.1016/j.ypmed.2004.09.016

Muhlenkamp, AF, & Brown, NJ. (1983). *The development of an instrument to measure health practices.* Paper presented at the American Nurses Association Council of Nurse Researchers Conference, Minneapolis, MN.

Mussap, Alexander J. (2006). Reinforcement sensitivity theory (RST) and body change behaviour in males. *Personality and Individual Differences, 40*(4), 841-852. doi: 10.1016/j.paid.2005.08.013

Mussap, Alexander J. (2007). Motivational processes associated with unhealthy body change attitudes and behaviours. *Eating Behaviors, 8*(3), 423-428. doi: 10.1016/j.eatbeh.2006.12.001

Muthén, LK, & Muthén, BO. (2007). Mplus. *Statistical analysis with latent variables. Version, 3*.

North, T. C., McCullagh, P. , & Tran, Z.V. (1990). Effect of exercise on depression. *Exercise and Sport Sciences Reviews, 18*, 379-415.

O'Connor, Brian P. (2002). A Quantitative Review of the Comprehensiveness of the Five-Factor Model in Relation to Popular Personality Inventories. *Assessment, 9*(2), 188-203. doi: 10.1177/1073191102092010

Ohmori, Y., Suzuki, N., Morita, A., Aiba, N., Miyachi, M., Watanabe, S., . . . Kimira, M. (2007). Association of Personality (NEO-Five Factor Inventory) with Eating Behaviors and Physical Activity Levels in Obese Subjects in the Saku Control Obesity Program (SCOP). *Anti-Aging Medicine, 4*(2), 43-50.

Parfitt, Gaynor, Rose, Elaine A., & Burgess, William M. (2006). The psychological and physiological responses of sedentary individuals to prescribed and preferred intensity exercise. *British Journal of Health Psychology, 11*(1), 39-53.

Paunonen, S. V., & Jackson, D. N. (2000). What is beyond the big five? Plenty! *Journal Of Personality, 68*(5), 821-835.

Pfungst, Oskar. (1911). *Clever Hans:(the horse of Mr. Von Osten.) a contribution to experimental animal and human psychology*: Holt, Rinehart and Winston.

Physical Activity Guidelines Advisory Committee. (2008). Physical Activity Guidelines Advisory Committee Report, 2008. Washington (DC): U.S. Department of Health and Human Services.

Poole, Lydia, Steptoe, Andrew, Wawrzyniak, Andrew J., Bostock, Sophie, Mitchell, Ellen S., & Hamer, Mark. (2011). Associations of objectively measured physical activity with daily mood ratings and psychophysiological stress responses in women. *Psychophysiology, 48*(8), 1165-1172. doi: 10.1111/j.1469-8986.2011.01184.x

Prochaska, James O, & Velicer, Wayne F. (1997). The transtheoretical model of health behavior change. *American journal of health promotion, 12*(1), 38-48.

Raykov, Tenko. (1997). Estimation of Composite Reliability for Congeneric Measures. *Applied Psychological Measurement, 21*(2), 173-184. doi: 10.1177/01466216970212006

Reed, Justy, & Buck, Sarah. (2009). The effect of regular aerobic exercise on positive-activated affect: A meta-analysis. *Psychology of Sport & Exercise, 10*(6), 581-594. doi: 10.1016/j.psychsport.2009.05.009

Reed, Justy, & Ones, Deniz S. (2006). The effect of acute aerobic exercise on positive activated affect: A meta-analysis. *Psychology of Sport & Exercise, 7*(5), 477-514. doi: 10.1016/j.psychsport.2005.11.003

Reuter, M., Stark, R., Hennig, J., Walter, B., Kirsch, P., Schienle, A., & Vaitl, D. (2004). Personality and Emotion: Test of Gray's Personality Theory by Means of an fMRI Study. *Behavioral Neuroscience, 118*(3), 462-469. doi: 10.1037/0735-7044.118.3.462

Revelle, William. (1995). Personality processes. *Annual Review Of Psychology, 46*, 295-295.

Rhodes, Ryan E., Courneya, Kerry S., & Jones, Lee W. (2002). Personality, the Theory of Planned Behavior, and Exercise: A Unique Role for Extroversion's Activity Facet1. *Journal of Applied Social Psychology, 32*(8), 1721-1736. doi: 10.1111/j.1559-1816.2002.tb02772.x

Rhodes, Ryan E., & Dickau, L. (2013). Moderators of the intention-behaviour relationship in the physical activity domain: a systematic review. *Br J Sports Med, 47*(4), 215-225. doi: 10.1136/bjsports-2011-090411

Rhodes, Ryan E., & Pfaeffli, L.A. (2012). Personality and Physical Activity. In Edmund O. Acevedo (Ed.), *The Oxford Handbook of Exercise Psychology* (pp. 195-). New York, New York: Oxford University Press.

Rhodes, Ryan E., & Smith, N. E. I. (2006). Personality correlates of physical activity:  A review and meta-analysis. *British Journal of Sports Medicine, 40*, 958-965.

Riemann, Rainer, Angleitner, Alois, & Strelau, Jan. (1997). Genetic and Environmental Influences on Personality: A Study of Twins Reared Together Using the Self- and Peer Report NEO-FFI Scales. *Journal of Personality, 65*(3), 449-475. doi: 10.1111/1467-6494.ep9710314565

Roberts, Brent W., Walton, Kate E. , & Viechtbauer, Wolfgang (2006). Patterns of mean-level change in personality traits across the life course:  a meta-analysis of longitudinal studies. *Psychological Bulletin, 132*(1), 1-25.

Rose, Elaine A., & Parfitt, Gaynor. (2007). A Quantitative Analysis and Qualitative Explanation of the Individual Differences in Affective Responses to Prescribed and Self-Selected Exercise Intensities. *Journal of Sport & Exercise Psychology, 29*(3), 281-309.

Rosenberg, M. S. (2005). The File-Drawer Problem Revisited:  A General Weighted Method for Calculating Fail-Safe Numbers in Meta-Analysis. *Evolution, 59*(2), 464-468.

Rosenthal, Robert. (1991). *Meta-Analytic Procedures for Social Research* (Vol. 6). Newbury Park: Sage Publications.

Rosenthal, Robert, & Jacobson, Lenore. (1968). Pygmalion in the classroom. *The Urban Review, 3*(1), 16-20.

Roth, D. L. (1989). Acute emotional and psychophysiological effects of aerobic exercise. *Psychophysiology, 26*(5), 593-602.

Russell, James A., & Carroll, James M. (1999a). On the bipolarity of positive and negative affect. *Psychological Bulletin, 125*(1), 3-30. doi: 10.1037/0033-2909.125.1.3

Russell, James A., & Carroll, James M. (1999b). The phoenix of bipolarity: Reply to Watson and Tellegen (1999). *Psychological Bulletin, 125*(5), 611-617. doi: 10.1037/0033-2909.125.5.611

Sanchez-Villegas, A, Ara, I, Guillen-Grima, F, Bes-Rastrollo, M, Varo-Cenarruzabeitia, JJ, & Martinez-Gonalez, MA. (2008). Phyislca activity, sedentary index, and mental disorders in the SUN cohort study. *Medicind and Science in Sports and Exercise, 40*, 827.

Schneider, M. L., & Graham, D. J. (2009). Personality, physical fitness, and affective response to exercise among adolescents. *Med Sci Sports Exerc, 41*(4), 947-955. doi: 10.1249/MSS.0b013e31818de009

Seedat, Soraya, Scott, Kate Margaret, Angermeyer, Matthias C, Berglund, Patricia, Bromet, Evelyn J, Brugha, Traolach S, . . . Jin, Robert. (2009). Cross-national associations between gender and mental disorders in the WHO World Mental Health Surveys. *Archives of general psychiatry, 66*(7), 785.

Shephard, R. J. (1997). Godin leisure-time exercise questionnaire. / Questionnaire de Godin sur le temps de loisir passe a faire de l ' exercice physique. *Medicine & Science in Sports & Exercise, 29*(6 Suppl.), S36-s38.

Shields, Morgan R., Larson, Christine L., Swartz, Ann M., & Smith, J. Carson. (2011). Visual threat detection during moderate- and high-intensity exercise. *Emotion, 11*(3), 572-581. doi: 10.1037/a0021251

Smith, Carson J., O'Connor, Patrick J., Crabbe, James B., & Dishman, Rod K. (2002). Emotional responsiveness after low- and moderate-intensity exercise and seated rest. *Medicine and Science in Sports and Exercise, 34*(7), 1158-1167.

Smits, Dirk J. M., & Boeck, P. D. (2006). From BIS/BAS to the big five. *European Journal of Personality, 20*(4), 255-270. doi: 10.1002/per.583

Steel, Piers, Schmidt, Joseph, & Shultz, Jonas. (2008). Refining the relationship between personality and subjective well-being. *Psychological Bulletin, 134*(1), 138-161. doi: 10.1037/0033-2909.134.1.138

Steinberg, Hannah, Nicholls, Briony R., Sykes, Elizabeth A., LeBoutillier, N., Ramlakhan, Nerina, Moss, T. P., & Dewey, Alison. (1998). Weekly exercise consistently reinstates positive mood. *European Psychologist, 3*(4), 271-280. doi: 10.1027/1016-9040.3.4.271

Sterne, Jonathan A C, & Harbord, R M. (2004). Funnel plots in meta-analysis. *Stata Journal, 4*(2), 127-141.

Sterne, Jonathan A C, Sutton, Alex J , Ioannidis, John P A , Terrin, Norma , Jones, David R , Lau, Joseph , . . . Higgins, Julian P T (2011). Recommendations for examining and interpreting funnel plot asymmetry in meta-analyses of randomised controlled trials. *BMJ, 343*. doi: 10.1136/bmj.d4002

Strawbridge, WJ, Deleger, S, Roberts, RE, & Kaplan, GA. (2002). Physical activity reduces the risk of subsequent depression for older adults. *American Journal of Epidemiology, 156*(4), 328-334.

Ströhle, Andreas. (2009). Physical activity, exercise, depression and anxiety disorders. *Journal of Neural Transmission, 116*(6), 777-784. doi: 10.1007/s00702-008-0092-x

Stubbe, J. H., Boomsma, D. I., Vink, J. M., Cornes, B. K., Martin, N. G., Skytthe, A., . . . de Geus, E. J. (2006). Genetic influences on exercise participation in 37,051 twin pairs from seven countries. *PLoS One, 1*, e22. doi: 10.1371/journal.pone.0000022

Stuettgen, Maik C., Hennig, Juergen, Reuter, Martin, & Netter, Petra. (2005). Novelty Seeking but not BAS is associated with high dopamine as indicated by a neurotransmitter challenge test using mazindol as a challenge substance. *Personality and Individual Differences, 38*(7), 1597-1608. doi: http://dx.doi.org/10.1016/j.paid.2004.09.025

SurveyMonkeyInc. (2011-2013). www.surveymonkey.com.

Sutton, Steven K., Davidson, Richard J., Donzella, Bonny, Irwin, William, & Dottl, Darren A. (1997). Manipulating affective state using extended picture presentations. *Psychophysiology, 34*(2), 217-226.

Takahashi, Yusuke, Yamagata, Shinji, Kijima, Nobuhiko, Shigemasu, Kazuo, Ono, Yutaka, & Ando, Juko. (2007). Continuity and change in behavioral inhibition and activation systems: A longitudinal behavioral genetic study. *Personality & Individual Differences, 43*(6), 1616-1625. doi: 10.1016/j.paid.2007.04.030

Tessier, Sabrina, Vuillemin, Anne, Bertrais, Sandrine, Boini, Stéphanie, Le Bihan, Etienne, Oppert, Jean-Michel, . . . Briançon, Serge. (2007). Association between leisure-time physical activity and health-related quality of life changes over time. *Preventive Medicine, 44*(3), 202-208. doi: DOI: 10.1016/j.ypmed.2006.11.012

Thayer, Robert E., Newman, J. Robert, & McClain, Tracey M. (1994). Self-regulation of mood: Strategies for changing a bad mood, raising energy, and reducing tension. *Journal of Personality and Social Psychology, 67*(5), 910-925. doi: 10.1037/0022-3514.67.5.910

Thomas, S., Reading, J., & Shephard, R. J. (1992). Revision of the Physical Activity Readiness Questionnaire (PAR-Q). *Canadian Journal of Sports Science, 17*(4), 338-345.

Tian, Qu, & Smith, J. Carson. (2011). Attentional bias to emotional stimuli is altered during moderate- but not high-intensity exercise. *Emotion, 11*(6), 1415-1424. doi: 10.1037/a0023568

Tolea, Magdalena, Terracciano, Antonio, Milaneschi, Yuri, Metter, E., & Ferrucci, Luigi. (2012). Personality Typology in Relation to Muscle Strength. *International Journal of Behavioral Medicine, 19*(3), 382-390.

Torrubia, Rafael, Avila, Cesar, & Caseras, Xavier. (2008). Reinforcement sensitivity scales: Is BAS better assessed from a multidimensional approach than a unidimensional one? In

Philip J. Corr (Ed.), *The Reinforcement Sensitivity Theory of Personality* (pp. 209-211). New York: Cambridge University Press.

Torrubia, Rafael, Ávila, César, & Caseras, Xavier. (2008). Reinforcement sensitivity scales. In Philip J. Corr (Ed.), *The reinforcement sensitivity theory of personality.* (pp. 188-227). New York, NY US: Cambridge University Press.

Torrubia, Rafael, Ávila, César, Moltó, Javier, & Caseras, Xavier. (2001). The Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ) as a measure of Gray's anxiety and impulsivity dimensions. *Personality and Individual Differences, 31*(6), 837-862. doi: 10.1016/s0191-8869(00)00183-5

Tottenham, N., Tanaka, J., Leon, A.C., McCarry, T., Nurse, M., Hare, T.A., . . . Nelson, C.A. (2009). The NimStim set of facial expressions: judgments from untrained research participants. *Psychiatry Research, 168*(3), 242-249.

Tudor-Locke, C. E., Bassett, David R., Shipe, Michael F., & McClain, James J. (2011). Pedometry Methods for Assessing Free-Living Adults. *Journal of Physical Activity & Health, 8*(3), 445-454.

Tudor-Locke, C. E., & Myers, A. M. (2001). Challenges and opportunities for measuring physical activity in sedentary adults. / Defis et opportunites pour la mesure de l'activite physique chez des adultes sedentaires. *Sports Medicine, 31*(2), 91-100.

US Department of Health and Human Services. (2010). Health People 2020. Washington, DC.

Vandenberg, R. J., & Lance, C. E. . (2000). A Review and Synthesis of the Measurement Invariance Literature: Suggestions, Practices, and Recommendations for Organizational Research. *Organizational Research Methods, 3*(1), 4-69.

Viken, Richard J., Rose, Richard J., Kaprio, Jaakko, & Koskenvuo, Markku. (1994). A developmental genetic analysis of adult personality: Extraversion and Neuroticism from 18 to 59 years of age. *Journal of Personality and Social Psychology, 66*(4), 722-730. doi: 10.1037/0022-3514.66.4.722

Voigt, Danielle C., Dillard, James P., Braddock, Kurt H., Anderson, Jason W., Sopory, Pradeep, & Stephenson, Michael T. (2009). BIS/BAS scales and their relationship to risky health behaviours. *Personality & Individual Differences, 47*(2), 89-93. doi: 10.1016/j.paid.2009.02.003

Wald, Abraham. (1943). Tests of Statistical Hypotheses Concerning Several Parameters When the Number of Observations is Large. *Transactions of the American Mathematical Society, 54*, 426-482.

Watson, David, & Clark, L. A. (1992). On traits and temperament: general and specific factors of emotional experience and their relation to the five-factor model. *Journal of Personality, 60*(2), 441-476.

Watson, David, & Tellegen, Auke. (1999). Issues in dimensional structure of affect—Effects of descriptors, measurement error, and response formats: Comment on Russell and Carroll (1999). *Psychological Bulletin, 125*(5), 601-610. doi: 10.1037/0033-2909.125.5.601

Watson, David, Wiese, David, Vaidya, Jatin, & Tellegen, Auke. (1999). The two general activation systems of affect: Structural findings, evolutionary considerations, and psychobiological evidence. *Journal of Personality and Social Psychology, 76*(5), 820-838. doi: 10.1037/0022-3514.76.5.820

Whaley, Mitchell H., Brubaker, Peter H., & Otto, Robert M. (Eds.). (2006). *ACSM's Guidelines for Exercise Testing and Prescription* (Seventh Edition ed.). Baltimore, MD: Lippincott Williams & Wilkins.

Williams, David M. (2008). Exercise, Affect, and Adherence: An Integrated Model and a Case for Self-Paced Exercise. *Journal of Sport & Exercise Psychology, 30*(5), 471-496.

Williams, David M., Dunsiger, Shira, Ciccolo, Joseph T., Lewis, Beth A., Albrecht, Anna E., & Marcus, Bess H. (2008). Acute affective response to a moderate-intensity exercise stimulus predicts physical activity participation 6 and 12 months later. *Psychology of Sport and Exercise, 9*(3), 231-245. doi: 10.1016/j.psychsport.2007.04.002

Wilson, DB. (2006). Meta-analsis macros for SAS, SPSS, and Stata. Retrieved September 1, 2013 http://mason.gmu.edu/~dwilsonb/ma.html

Wilson, KE, & Dishman, RK. (2014). *Personality and Physical Activity: A Systematic Review and Meta-Analysis*. In review.

Wise, LA, Adams-Campbell, LL, Palmer, JR, & Rosenberg, L. (2006). Leisure time physical activity in relation to depressive symptoms in the Black Women's Health Study. *Annals of Behavioral Medicine, 32*(1), 68-76.

Witt, L. A. (2002). The Interactive Effects of Extraversion and Conscientiousness on Performance. *Journal of Management, 28*(6), 835-851. doi: http://dx.doi.org/10.1016/S0149-2063(02)00188-5

Wolin, KY, Glynn, RJ, Colditz, GA, Lee, IM, & Kawachi, I. (2007). Long-term physical activity patterns and health-related quality of life in U.S. women. *American Journal of Preventive Medicine, 32*(6), 490.

Yeung, Robert R. (1996). The acute effects of exercise on mood state. *Journal of Psychosomatic Research, 40*(2), 123-141. doi: 10.1016/0022-3999(95)00554-4

Zuckerman, Marvin. (2005). *Psychobiology of Personality* (2 ed. Vol. 2). Cambridge, England: Cambridge University Press.

Zuckerman, Marvin, Joireman, Jeffrey, Kraft, Michael, & Kuhlman, D. Michael. (1999). Where do motivational and emotional traits fit within three factor models of personality? *Personality and Individual Differences, 26*(3), 487-504. doi: 10.1016/s0191-8869(98)00161-5

# APPENDIX A

## Scale Items for the Measurement of Psychological Constructs in Chapter 3

**International Personality Item Pool – Extraversion and Neuroticism**

Response options: 1 = very accurate, 2 = moderately accurate, 3 = neither accurate nor inaccurate, 4 = moderately inaccurate, 5 = very inaccurate.

1. Am the life of the party
2. Get stressed out easily
3. Don’t talk a lot
4. Feel comfortable around people
5. Worry about things
6. Keep in the background
7. Seldom feel blue
8. Start conversations
9. Am easily disturbed
10. Have little to say
11. Get upset easily
12. Talk to a lot of different people at parties
13. Change my mood a lot
14. Don’t like to draw attention to myself
15. Have frequent mood swings
16. Don’t mind being the center of attention

17. Get irritated easily

18. Am quiet around strangers

19. Often feel blue

20. Am relaxed most of the time

Extraversion: 1*, 3, 4*, 6, 8*, 10, 12*, 14, 16*, 18
Neuroticism: 2, 5, 7*, 9, 11, 13, 15, 17, 19, 20*
*Reverse Scored

**BIS/BAS Scales**

Response options:
1 = very false for me
2 = somewhat false for me
3 = somewhat true for me
4 = very true for me.

1. A person's family is the most important thing in life.

2. Even if something bad is about to happen to me, I rarely experience fear or nervousness.

3. I go out of my way to get things I want.

4. When I'm doing well at something I love to keep at it.

5. I'm always willing to try something new if I think it will be fun.

6. How I drew is important to me.

7. When I get something I want, I feel excited and energized.

8. Criticism or scolding hurts me quite a bit.

9. When I want something I usually go all-out to get it.

10. I will often do things for no other reason than that they might be fun.

11. It's hard for me to find the time to do things such as get a haircut.

12. If I see a chance to get something I want I move on it right away.

13. I feel pretty worried or upset when I think or know somebody is angry at me.

14. When I see an opportunity for something I like, I get excited right away.

15. I often act on the spur of the moment.

16. If I think something unpleasant is going to happen, I usually get pretty “worked up.”

17. I often wonder why people act the way they do.

18. When good things happen to me, it affects me strongly.

19. I feel worried when I think I have done poorly at something important.

20. I crave excitement and new sensations.

21. When I go after something I use a “no holds barred“ approach.

22. I have very few fears compared to my friends.

23. It would excite me to win a contest.

24. I worry about making mistakes.

BIS: 2*, 8, 13, 16, 19, 22*, 24
Drive: 3, 9, 12, 21
Fun Seeking: 5, 10, 15, 20
Reward Responsiveness: 4, 7, 14, 18, 23
Items 1, 6, 11, and 17 are fillers.
*Reverse Scored

**SF-36 Mental Health**

Response options:
1 = all of the time
2 = most of the time
3 = a good bit of the time
4 = some of the time
5 = a little of the time
6 = none of the time.

9b. Have you been a very nervous person?

9c. Have you felt so down in the dumps that nothing could cheer you up?

9d. Have you felt calm and peaceful?

9f. Have you felt downhearted and blue?

9. Have you been a happy person?

Reverse scored items: 9d and 9h

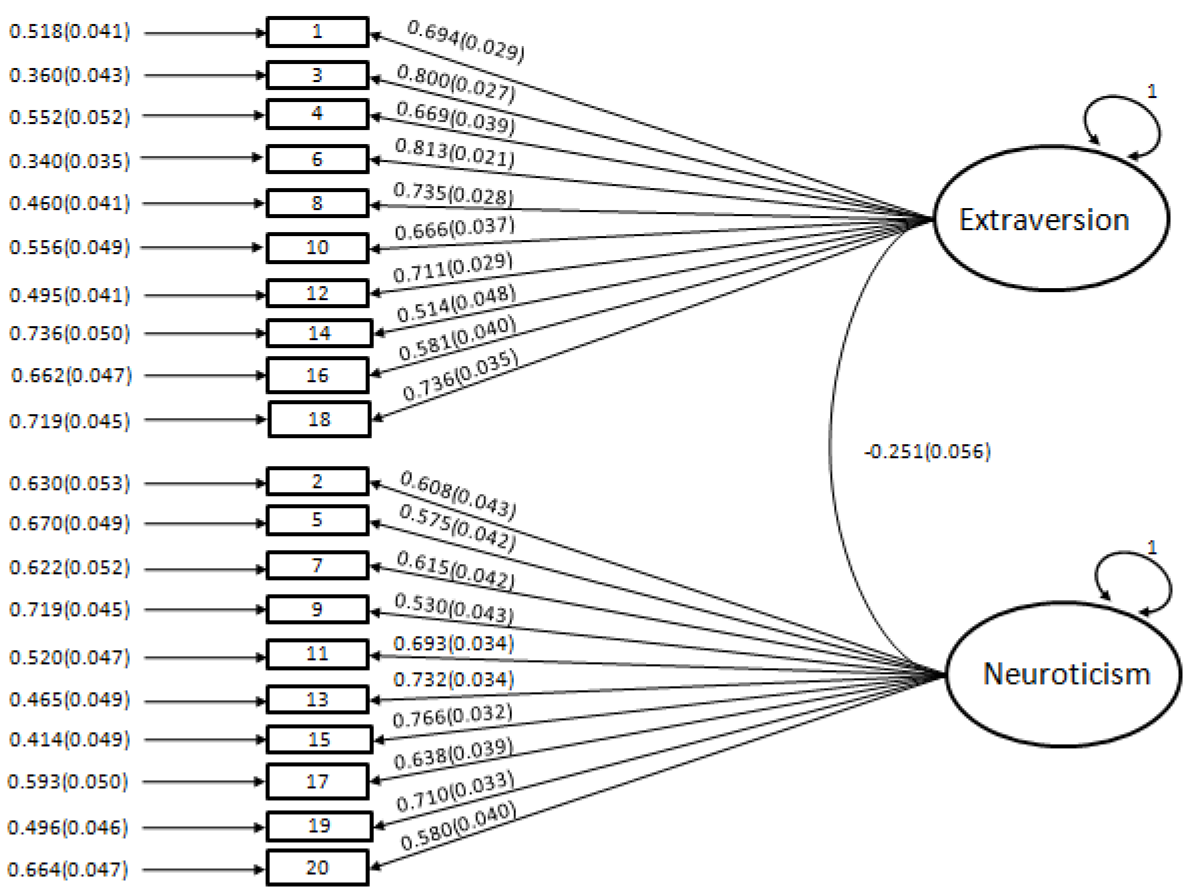
**K10 Mental Distress Scale**

Response options:
1 = None of the time
2 = A little of the time
3 = Some of the time
4 = Most of the time
5 = All of the time.

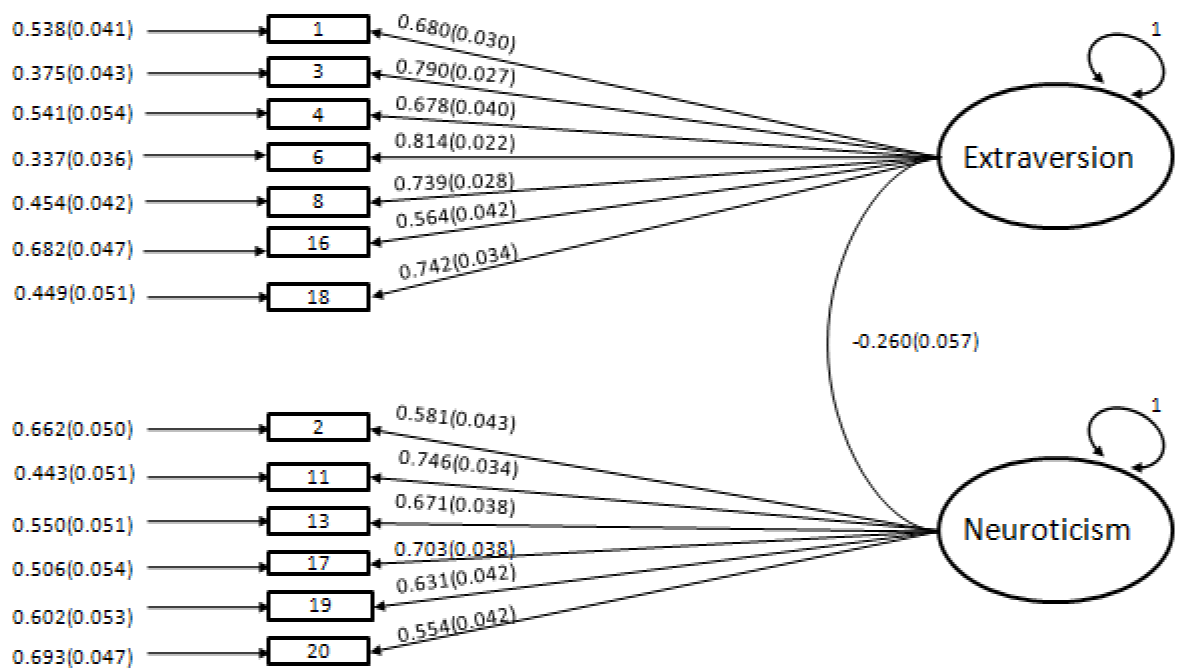
1. During the last 30 days, about how often did you feel tired out for no good reason?
2. During the last 30 days, about how often did you feel nervous?
3. During the last 30 days, about how often did you feel so nervous that nothing could calm you down?
4. 4. During the last 30 days, about how often did you feel hopeless?
5. During the last 30 days, about how often did you feel restless or fidgety?
6. During the last 30 days, about how often did you feel so restless you could not sit still?
7. During the last 30 days, about how often did you feel depressed?
8. During the last 30 days, about how often did you feel that everything was an effort?
9. During the last 30 days, about how often did you feel so sad that nothing could cheer you up?
10. During the last 30 days, about how often did you feel worthless?

APPENDIX B

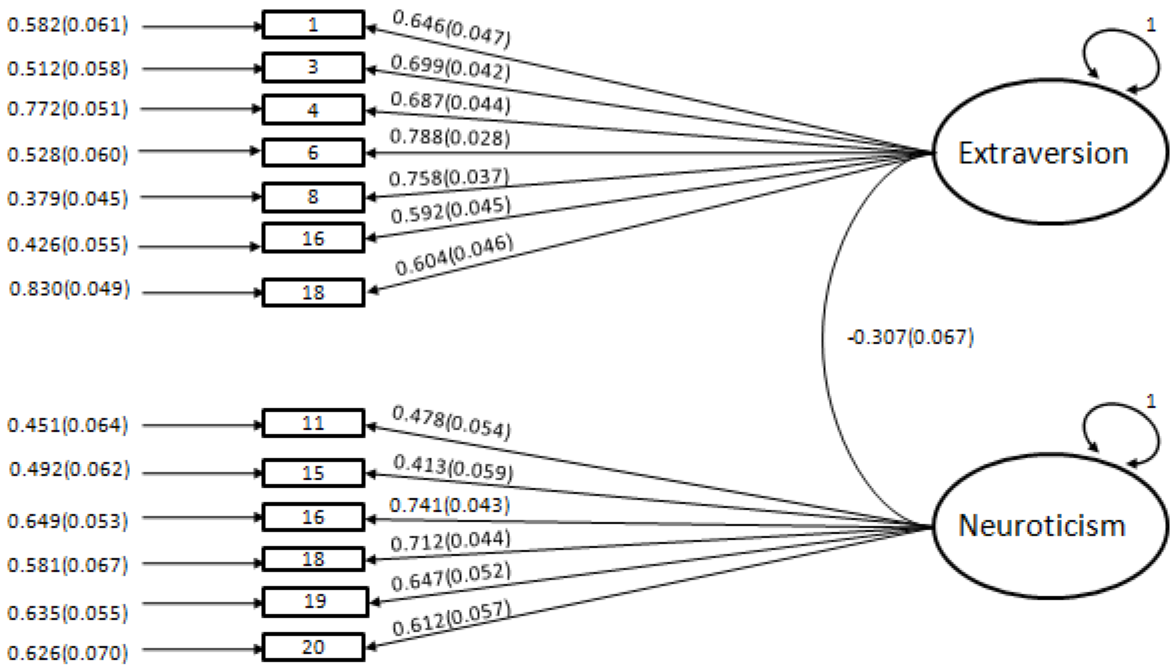
**CFA Models for Psychological Constructs Measured in Chapter 3**



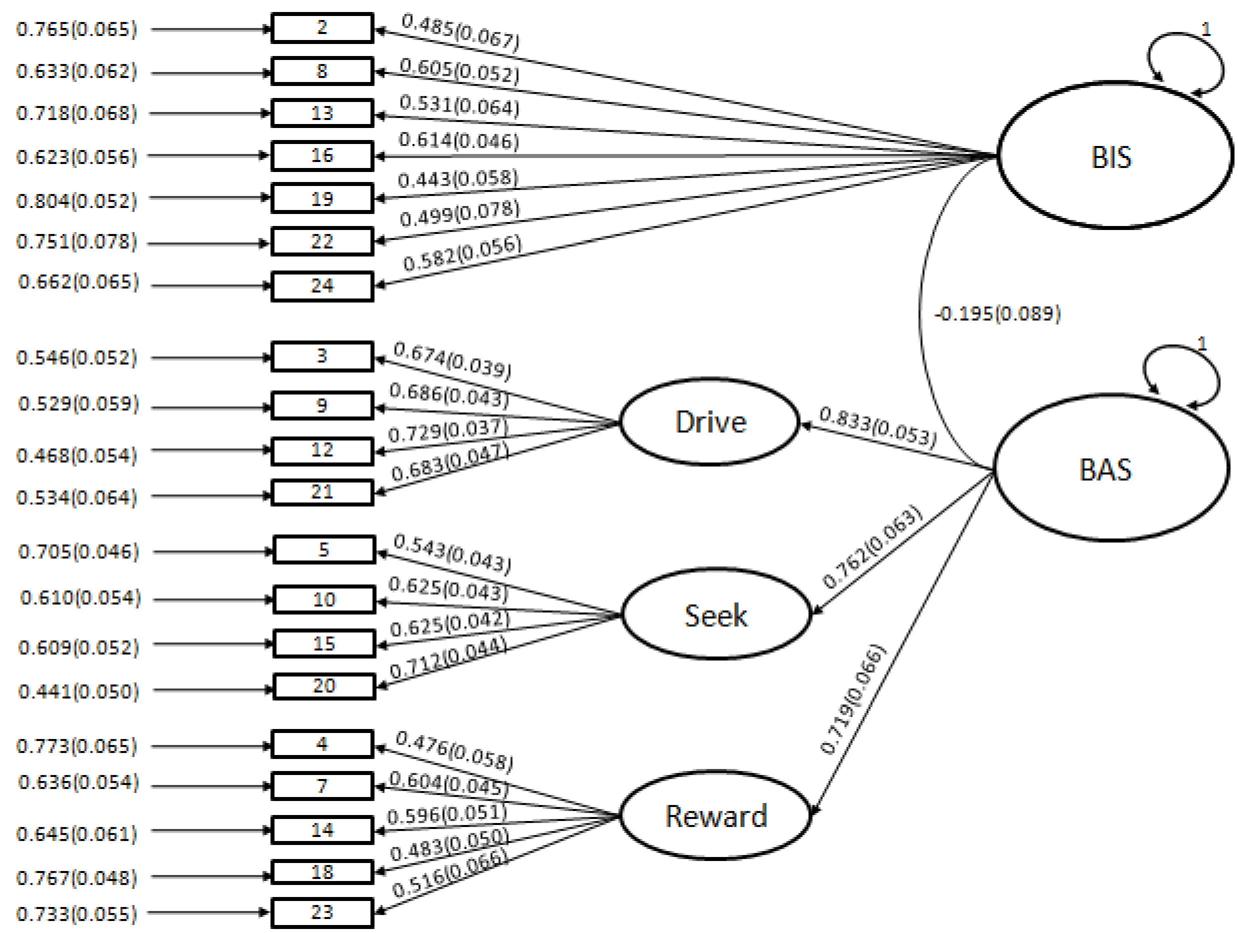

CFA of IPIP Extraversion and Neuroticism Scales in Sample 1
N = 403.
$\chi^2$ (df) = 755.582 (169); RMSEA (90% CI) = 0.093 (0.086, 0.100); CFI = 0.826; TLI = 0.804; SRMR = 0.071



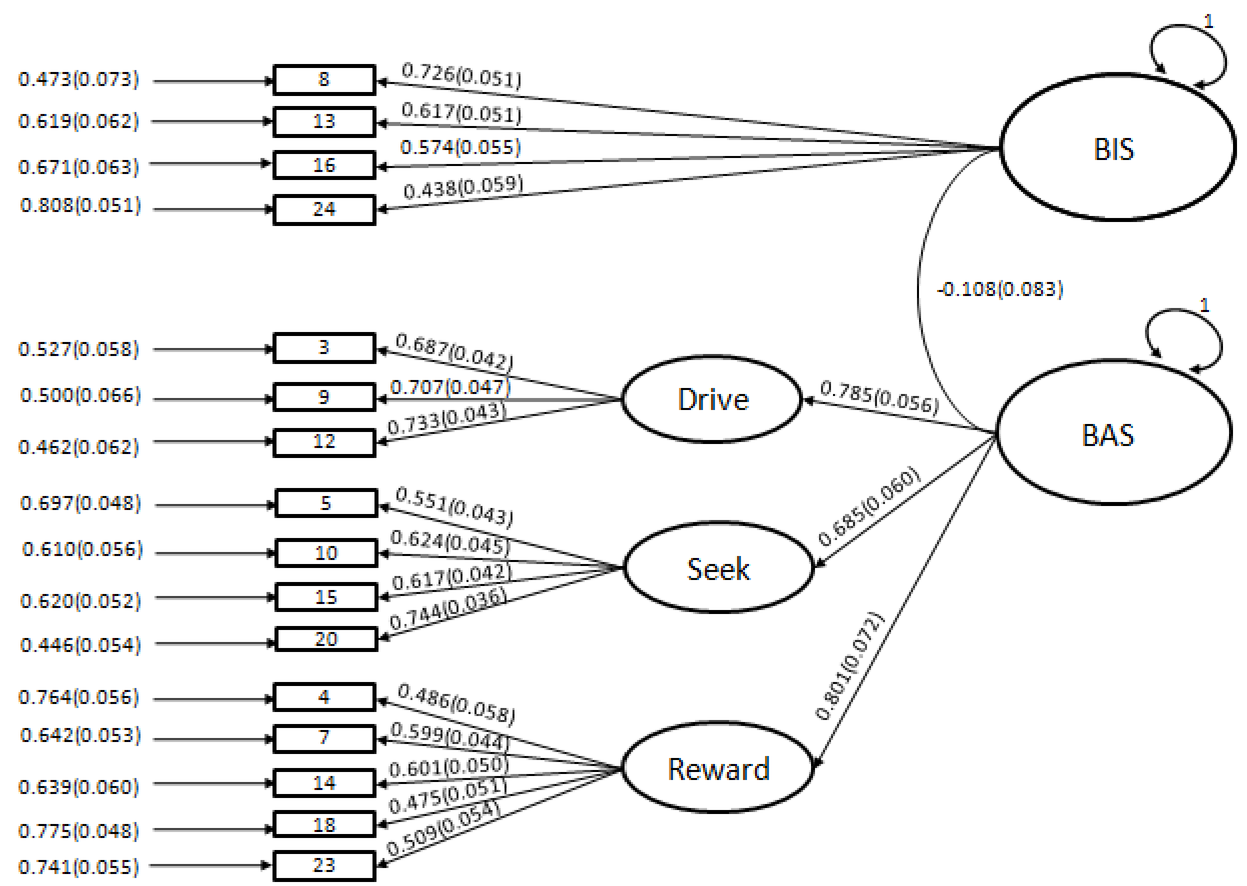

CFA of Trimmed Extraversion and Neuroticism Scales in Sample 1
N = 403.
$\chi^2$ (df) = 190.953 (64); RMSEA (90% CI) = 0.070 (0.059, 0.082); CFI = 0.928; TLI = 0.912; SRMR = 0.064



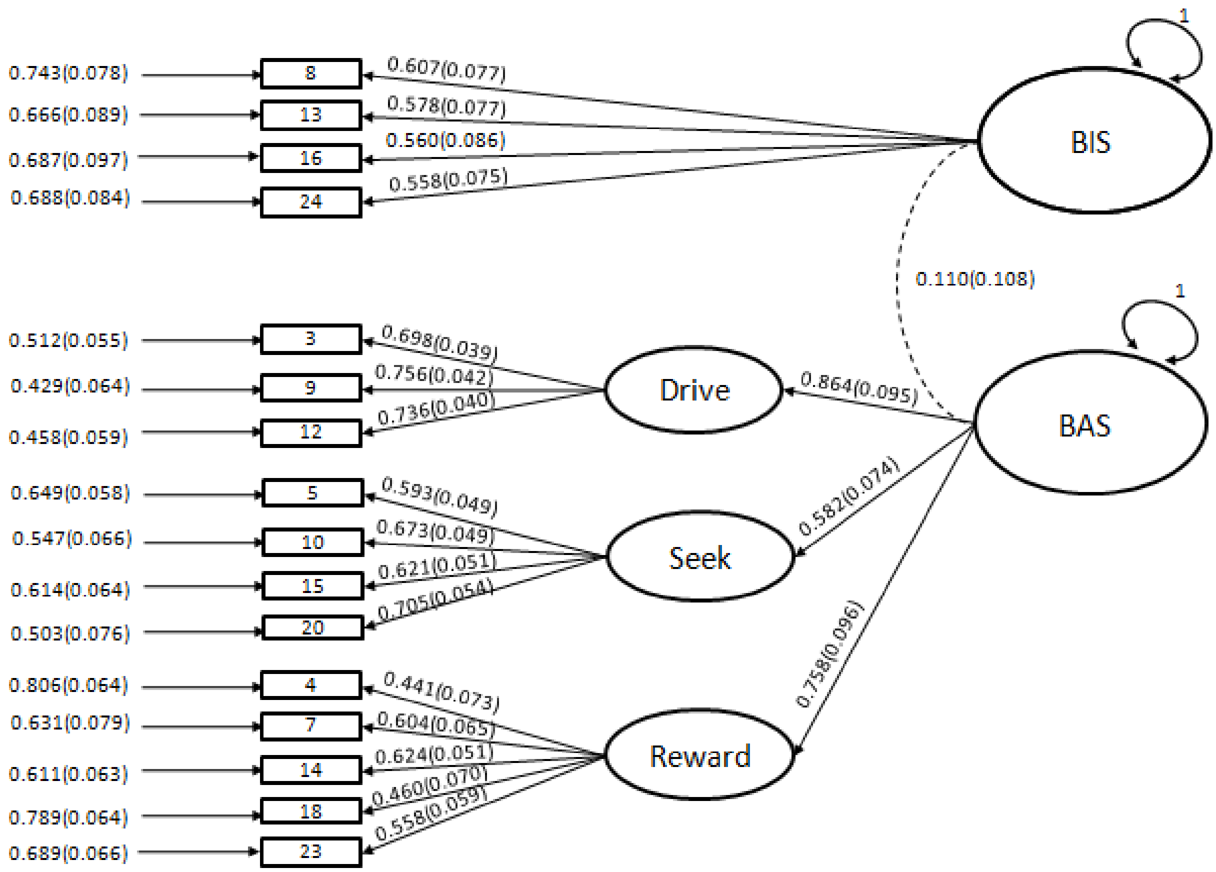

CFA of Trimmed Extraversion and Neuroticism Scales in Sample 2
N = 297.
$\chi^2$ (df) = 126.836 (64); RMSEA (90% CI) = 0.057 (0.043, 0.072); CFI = 0.940; TLI = 0.927; SRMR = 0.053



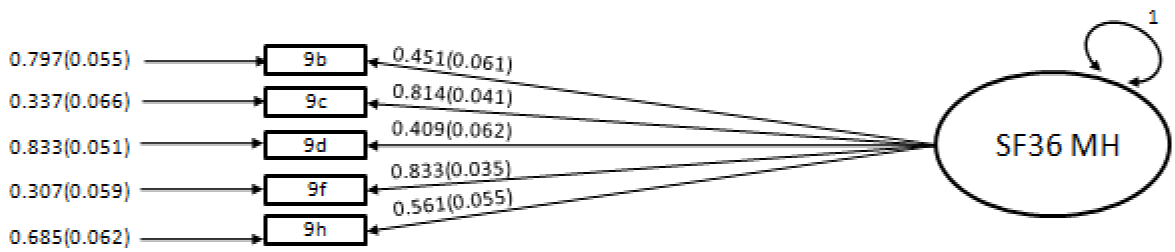

CFA of BIS/BAS Scales in Sample 1
N = 409.
$\chi^2$ (df) = 471.768 (166); RMSEA (90% CI) = 0.067 (0.060, 0.074); CFI = 0.825; TLI = 0.800; SRMR = 0.087



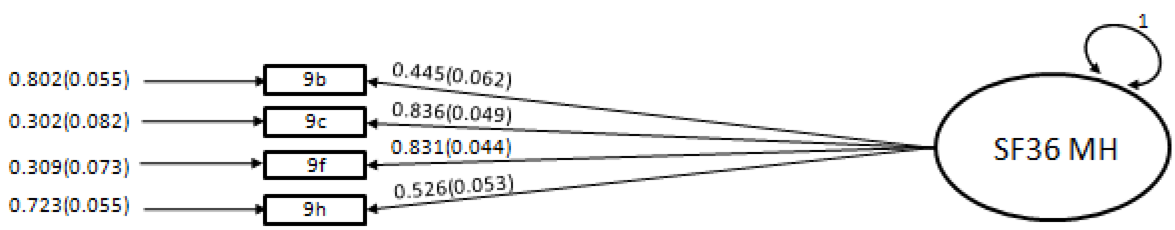

CFA of Trimmed BIS/BAS Scales in Sample 1
N = 409.
$\chi^2$ (df) = 203.144(100); RMSEA (90% CI) = 0.051 (0.041, 0.061); CFI = 0.916; TLI = 0.899; SRMR = 0.056




CFA of Trimmed BIS/BAS Scales in Sample 2
N = 295.
$\chi^2$ (df) = 163.904 (100); RMSEA (90% CI) = 0.047 (0.033, 0.059); CFI = 0.926; TLI = 0.911; SRMR = 0.065




CFA of SF-36 Mental Health Scale in Sample 2
N = 297.
$\chi^2$ (df) = 47.275 (5); RMSEA (90% CI) = 0.169 (0.127, 0.214); CFI = 0.872; TLI = 0.745; SRMR = 0.064




CFA of Trimmed SF-36 Mental Health Scale in Sample 2
N = 297.
$\chi^2$ (df) = 0.004 (2); RMSEA (90% CI) = <0.001 (<0.001, <0.001); CFI = 1.000; TLI = 1.026; SRMR = 0.001