Psychological Bulletin

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Online First Publication, May 11, 2017. http://dx.doi.org/10.1037/bul0000105

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0033-2909/17/$12.00 http://dx.doi.org/10.1037/bul0000105

Questionnaire and Behavioral Task Measures of Impulsivity are Differentially Associated With Body Mass Index: A Comprehensive Meta-Analysis

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Although impulsivity has been implicated in the development and maintenance of obesity, evidence linking impulsivity to obesity has been mixed. These mixed findings may be related to differences in the type of impulsivity measures used and the varied domains of impulsivity assessed by each measure. The present meta-analysis aimed to examine the impact of measurement selection on the relationship between impulsivity and body mass index (BMI). A total of 142 articles met inclusion criteria and were comprised of 315,818 participants. Effect sizes consisted of Fisher's z-transformed correlation coefficients, which were weighted by the inverse variance to establish the grand mean estimate of the relationship between impulsivity and BMI. Overall weighted mean effect sizes also were computed for each type and domain of impulsivity measure. Moderator analyses were conducted using a mixed-effects approach to determine if the relationship between impulsivity and BMI varied between the types of impulsivity measures used. On average, participants were 32.25 (SD = 12.41) years of age, with a BMI of 26.63 (SD = 5.73) kg/m^2. The overall relationship between impulsivity and BMI was small but significant (r = .07). Behavioral task measures of impulsivity produced significantly larger effect sizes (r = .10) than did questionnaire measures of impulsivity (r = .05). Domains of impulsivity that assessed disinhibited behaviors (r = .10), attentional deficits (r = .11), impulsive decision-making (r = .10), and cognitive inflexibility (r = .17) produced significant effect sizes. These meta-analytic findings demonstrate that impulsivity is positively associated with BMI and further document that this association varies by the type of impulsivity measure used and the domain of impulsivity assessed.

Keywords: impulsivity, obesity, body mass index, meta-analysis

Supplemental materials: http://dx.doi.org/10.1037/bul0000105.supp

Obesity is an increasingly prevalent, yet preventable, cause of death that is associated with significant physical (Bray, 2004), psychosocial (Carr & Friedman, 2005; Puhl & Brownell, 2001), and financial consequences (Finkelstein et al., 2008; Withrow & Alter, 2011). Although the prevalence of obesity has been attributed to numerous environmental factors (Fairburn & Brownell, 2002), individual differences in weight status indicate that not everyone who is exposed to an obesogenic environment becomes obese. Indeed, individual variability in biological and psychological factors promotes differential responses to environmental triggers, leading some individuals to be susceptible to weight gain and others resistant (Blundell et al., 2005). Accordingly, identifying factors that contribute to individual differences in weight status has important implications for obesity prevention and treatment efforts.

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An extensive body of research has identified correlates of obesity, with a growing line of inquiry focusing on the role of individual personality traits. Personality traits are considered enduring personal characteristics that influence how individuals perceive and interact with their environment and have been implicated in the etiology and prognosis of myriad conditions (Adler & Matthews, 1994; Boersma, Benthem, van Beek, van Dijk, & Scheurink, 2011; Bogg & Roberts, 2004; Jokela et al., 2014; Jokela et al., 2013). Impulsivity, a personality trait generally defined as a tendency to act on immediate urges either before or despite consideration of negative consequences (DeYoung, 2010), has gained notable attention as a risk factor for the development and maintenance of obesity. Accumulating research has identified socioenvironmental factors (e.g., Arcelus, Haslam, Farrow, & Meyer, 2013; Elfhag & Morey, 2008; Guerrieri, Nedekoorn, & Jansen, 2008b), health-related behaviors (e.g., Schag, Schonleber, Teufel, Zipfel, & Giel, 2013; Waxman, 2009; Wilson & Dishman, 2015), and neurobiological mechanisms (e.g., Appelhans, 2009; Chamberlain & Sahakian, 2007; Dalley, Mar, Economidou, & Robbins, 2008) through which impulsivity promotes obesity. However, despite the substantial evidence linking impulsivity to behaviors that confer obesity risk, comprehensive reviews of the literature have highlighted inconsistencies in both the magnitude and directionality of the overall association between impulsivity and obesity (Fitzpatrick, Gilbert, & Serpell, 2013; Jokela et al., 2013; Thamotharan, Lange, Zale, Huffhines, & Fields, 2013; Vainik, Dagher, Dube, & Fellows, 2013).

These mixed findings may be partly explained by a general lack of consensus regarding the operationalization of impulsivity (van den Akker, Stewart, Antoniou, Palmberg, & Jansen, 2014). Throughout the literature, impulsivity has been conceptualized as either a unidimensional construct or a group of distinct phenotypes that manifest in similar behavioral patterns (Sharma, Markon, & Clark, 2014). This lack of conceptual consensus has fostered the development of diverse models and measures of impulsivity, which have limited convergent validity (Duckworth & Kern, 2011; Lane, Cherek, Pietras, & Tcheremissine, 2003; Reynolds, Ortengren, Richards, & de Wit, 2006) and instead appear to measure distinct impulsigenic traits (Sharma et al., 2014). Given the widely varied and inconsistent conceptualizations of impulsivity across the obesity literature, the relationship between impulsivity and obesity may depend both on the way in which impulsivity is measured and the specific domain of impulsivity assessed.

This article will provide a review and quantitative synthesis of the extant literature by critically examining the impact of measurement selection on the complex relationship between impulsivity and obesity. The association between impulsivity and obesity first will be introduced through an overview of the literature, with a focus on relevant theories and known mediational processes. A detailed overview of measurements commonly used to assess impulsivity and the unique psychometric challenges that accompany each type of measure then will be provided as will an empirical framework with which to conceptualize measures of impulsivity into distinct domains. In the face of numerous operational definitions of impulsivity as a construct, we elected to use the factor structure outlined by a recent meta-analytic principal-components analysis conducted by Sharma, Markon, and Clark (2014), which has received increasing support as a means to hierarchically organize distinct domains of impulsivity measures. Finally, meta-analytic techniques will be used to test whether the association between impulsivity and body mass index (BMI), a widely used and well validated proxy measure of adiposity (Welborn & Dhaliwal, 2007), varies as a function both of the type of impulsivity measure used and the particular domain of impulsivity assessed. By examining whether specific impulsigenic traits are differentially associated with BMI, this article ultimately aims to clarify both who may be at risk for obesity and how those individuals may be at risk.

Impulsivity and Obesity

Obesity is a disorder of sustained positive energy balance (Epstein, Leddy, Temple, & Faith, 2007), occurring when the amount of energy consumed is greater than the amount of energy expended (Blundell & Cooling, 2000). Energy balance is determined by variability in energy intake and expenditure, which are regulated by a variety of biological, psychological, and environmental mechanisms (Blundell & Cooling, 2000; DeLany, 2012) that interact to differentially predict risk for obesity (Carnell & Wardle, 2008; Epstein et al., 2007; Hartmann, Czaja, Rief, & Hilbert, 2010; Martins, Morgan, & Truby, 2008; Martins, Robertson, & Morgan, 2010; Waxman, 2009). Although understanding the multifactorial processes implicated in the etiology and maintenance of obesity has profound implications for the development of effective prevention and treatment efforts, reviews of the literature suggest that the interplay between psychological characteristics and environmental factors is particularly suited for determining the regulation of food intake and physical activity compared with the role of biological mechanisms alone (Boersma et al., 2011; Levitsky, 2005).

Personality traits serve as reliable predictors of how an individual will engage with and respond to socioenvironmental stimuli (Mischel & Shoda, 1995) and are recognized as valuable determinants of health outcomes in both the psychological and biomedical communities (Harper, 2004). Personality traits develop from a combination of genetic and environmental influences (Krueger, South, Johnson, & Iacono, 2008; McCrae, Jang, Livesley, Riemann, & Angleitner, 2001) and remain relatively stable across the life span (Roberts & DelVecchio, 2000). Numerous models have been proposed to explain how personality promotes or protects against disease states (Adler & Matthews, 1994; Deci & Ryan, 2008; Montano, Kasprzyk, Glanz, Rimer, & Viswanath, 2008; Smith, 2006; Ursin, 1980), and there now exists widespread agreement that personality traits influence health processes through their action on socioenvironmental factors, health-related behaviors, and psychophysiological mechanisms (Adler & Matthews, 1994; Smith, 2006). Thus, individual differences in personality may be especially useful in distinguishing who is likely to become obese and under what environmental circumstances this likelihood is altered (Boersma et al., 2011).

Impulsivity is one personality trait that has been shown to augment risk for a multitude of psychiatric and medical conditions, including substance use disorders (de Wit, 2009), attention-deficit/hyperactivity disorder (Winstanley, Eagle, & Robbins, 2006), bipolar disorder (Swann, 2009), eating disorders (Waxman, 2009), borderline personality disorder (Bornovalova, Lejuez, Daughters, Zachary Rosenthal, & Lynch, 2005), and obesity (Guerrieri, Nederkoorn, & Jansen, 2008a). Although a more detailed definition of impulsivity as a construct is provided in the following section, impulsivity generally is conceptualized as a tendency to act on immediate urges either before or despite consideration of negative consequences (DeYoung, 2010). Consistent with developmental theories of personality (Rothbart, 2007), impulsivity begins to emerge during late infancy and early childhood and persists into adulthood (Caspi et al., 2003; Caspi & Silva, 1995). Although there is a general decline in impulsivity that occurs with age (Steinberg et al., 2008), individuals who begin adolescence high on impulsivity continue to be more impulsive as adults than do individuals who begin adolescence low on impulsivity (Quinn & Harden, 2013), indicating that impulsivity is an enduring individual characteristic that may serve as an important health risk indicator, particularly in relation to obesity.

Obesity broadly is associated with a propensity toward palatable foods (Davis & Fox, 2008; Davis et al., 2007; Davis, Strachan, & Berkson, 2004), difficulty delaying rewards (Jarmolowicz et al., 2014), disinhibited behaviors (Hays & Roberts, 2008), and elevated emotional reactivity (Elfhag & Morey, 2008; Laitinen, Ek, & Sovio, 2002), all of which reflect impulsive processes. Extensive cross-sectional research indeed has documented a positive association between impulsivity and weight status (Brogan, Hevey, O'Callaghan, Yoder, & O'Shea, 2011; Franken & Muris, 2005; Lillis, Levin, & Trafton, 2012; Meule & Platte, 2015; Mobbs, Crépin, Thiéry, Golay, & Van der Linden, 2010), with prospective evidence further demonstrating that impulsive personality traits are related to increased weight gain over time (Armon, Melamed, Shirom, Shapira, & Berliner, 2013; Sutin, Ferrucci, Zonderman, & Terracciano, 2011). Impulsivity also is frequently cited as a predictor of poor treatment outcomes during weight loss intervention (Nederkoorn, Jansen, Mulkens, & Jansen, 2007; Sullivan, Cloninger, Przybeck, & Klein, 2007; Witbracht, Laugero, Van Loan, Adams, & Keim, 2012). Taken together, these findings indicate that impulsivity is associated with factors that aid in both the facilitation of weight gain and the inhibition of weight loss, which has prompted considerable research efforts aimed at uncovering the neurobiological and behavioral mechanisms through which impulsivity promotes the development and maintenance of obesity.

A majority of this research has focused on the contributory effects of impulsivity on the behaviors characteristic of obesity. Obesity predominantly develops as a function of problematic eating behaviors that favor the attainment of a positive energy balance and are determined by a complex set of phenomena that influence food choice as well as the quantity of food consumed and the frequency of eating episodes (Blundell & Cooling, 2000). For instance, the overconsumption of palatable foods high in fats and sugar is a hallmark eating behavior of obesity that primarily is driven by hedonic rather than homeostatic factors (Blundell & Finlayson, 2004). Similar to other addictive substances, palatable foods are potent activators of neural reward networks that influence motivation to engage in appetitive behavior (Appelhans, 2009). Obesity is associated with a heightened attention to palatable food cues (Stoeckel et al., 2008), an increased drive to eat palatable foods (Schultes, Ernst, Wilms, Thurnheer, & Hallschmid, 2010), and the consumption of palatable foods in the absence of hunger (Barkeling, King, Naslund, & Blundell, 2007), which together reflect a general preference for and sensitivity to the rewarding properties of palatable foods.

Given that impulsivity is associated with neurobiological mechanisms that potentiate sensitivity to rewards (Kirby, Zeeb, & Winstanley, 2011; Volkow, Fowler, Wang, & Swanson, 2004), individuals high on impulsivity may be particularly likely to prefer the hedonic properties of palatable foods over healthier options, placing them at heightened risk for obesity. Davis and colleagues tested this hypothesis in a series of studies by assessing the relationship between impulsive personality traits linked to reward sensitivity, food preferences, and overeating in women of varying weight status (Davis & Fox, 2008; Davis et al., 2007; Davis et al., 2004). Using structural equation modeling, the authors found that these impulsive personality traits were positively associated with overeating and a preference for palatable foods, which were, in turn, related to having a higher weight status (Davis et al., 2007). Interestingly, this finding was not consistently demonstrated among individuals with obesity (Davis & Fox, 2008; Davis et al., 2004), which may be indicative of a downregulation of the neural reward system due to repeated overstimulation. Indeed, individuals with severe obesity have been shown to develop a tolerance for the rewarding effects of palatable foods over time and must consume a greater quantity of such foods to experience the same level of reward (Wang et al., 2001), a pathophysiologic process characteristic of addiction (Volkow & Wise, 2005).

Though the findings from this line of research indicate that a heightened sensitivity to reward promotes a penchant for and preferential selection of palatable foods, reward sensitivity is not the only impulsive process implicated in the control of palatable food intake. Appelhans (2009) argued that overeating behavior is influenced by the interactive effects of reward sensitivity and inhibitory control. The capacity to inhibit food intake is governed by the prefrontal cortex, and a relative deficiency in executive functioning is thought to increase vulnerability to overeat when exposed to palatable food cues (Alonso-Alonso & Pascual-Leone, 2007; Appelhans, 2009). Accordingly, individuals high on impulsivity, who display general deficits in executive processes associated with attention (Weissman, Roberts, Visscher, & Woldorff, 2006), inhibition (Garavan, Ross, Murphy, Roche, & Stein, 2002), and decision-making (Peters & Büchel, 2009; Platt & Huettel, 2008), may be particularly likely to overeat. In support of this notion, neuroimaging research has shown that individuals with overweight or obesity, who also are high on impulsivity, demonstrate broad dysfunctions in executive processing that leads to an attentional bias to food cues (Lawrence, Hinton, Parkinson, & Lawrence, 2012), difficulty inhibiting behavioral responses to food (Hege et al., 2015), and a preference for immediate over delayed rewards (Stoeckel, Murdaugh, Cox, Cook, & Weller, 2013). Therefore, the overeating behavior observed among individuals high on impulsivity may partly result from a heightened appetitive motivation to consume palatable food that easily exceeds their already diminished capacity to maintain inhibitory control.

Although a complete review of the neurobiological and behavioral mechanisms that contribute to the expression of obesogenic behaviors among individuals high on impulsivity is beyond the scope of this article, the findings reviewed above provide support for an increasingly tested conceptual model of feeding that links impulsivity to obesity through dysfunctional systems associated with reward sensitivity and inhibition (Appelhans, 2009). However, despite mounting evidence documenting a relationship between impulsivity and processes that confer obesity risk (Guerrieri et al., 2008a), comprehensive reviews of the literature have highlighted numerous inconsistencies in the magnitude and directionality of the overall association between impulsivity and obesity (Fitzpatrick et al., 2013; Jokela et al., 2013; Thamotharan et al., 2013; Vainik et al., 2013). These discrepant findings subsequently have led to both confusion and disagreement among the scientific community about whether and how impulsivity relates to obesity. In a recent conceptual report, van den Akker, Stewart, Antoniou, Palmberg, and Jansen, (2014) speculated that these mixed findings may partly be explained by a general lack of consensus regarding the operationalization of impulsivity and called for the development of a standardized approach to defining and measuring impulsivity in obesity research. However, limited efforts have attempted to systematically clarify which impulsivity constructs are most relevant for the study of obesity.

Measurement of Impulsivity

There historically has been limited consensus regarding the operationalization of impulsivity. Although early personality theorists viewed impulsivity as a unidimensional construct (Guilford, 1939), current conceptualizations recognize impulsivity as a broad trait comprising several distinct impulsive phenotypes that manifest in similar behavioral patterns (Sharma et al., 2014; Whiteside & Lynam, 2001). Researchers consequently have developed many diverse models and measures of impulsivity, which ultimately has served to further complicate our understanding of impulsivity as a construct. At present, impulsivity most commonly is assessed through two broad measurement modalities, including questionnaire measures of impulsivity and behavioral task measures of impulsivity. Questionnaire measures of impulsivity include self-report assessments of trait impulsive characteristics whereas behavioral task measures of impulsivity include performance-based assessments of impulsive behaviors. Although both questionnaire and behavioral task measures of impulsivity offer researchers several advantages to assessing impulsivity, they also are accompanied by unique psychometric challenges as detailed below.

Questionnaire Measures of Impulsivity

Questionnaire measures of impulsivity assess stable personality traits that contribute to impulsive characteristics by asking respondents to rate the extent to which they engage in impulsive behaviors. Questionnaire measures of impulsivity offer several advantages to investigators as they are quick and inexpensive to administer and provide an efficient method to assess trait impulsive characteristics among large groups of individuals. Questionnaire measures indeed are the most common method of assessment for impulsivity in personality and individual difference research. However, questionnaire measures of impulsivity have long been criticized for their use of divergent scale content and construction, making it difficult to compare results across measures or integrate findings.

Several efforts have attempted to remedy the issues surrounding the conceptualization and measurement of impulsive personality traits. Preliminary findings by Lynam (Lynam & Miller, 2004; Whiteside & Lynam, 2001) and Smith (Cyders & Smith, 2007; Smith et al., 2007) provided initial evidence that omnibus questionnaire measures of impulsivity are best characterized by four modestly associated but distinct impulsive factors that lead to rash action. Meanwhile, Carver (2005) expanded on prior theories of reinforcement sensitivity (Gray, 1970) and proposed an integrated, dual-process model by arguing that impulsive personality traits are best conceptualized as deriving from two neurological systems that work in concert to determine approach and avoidance behaviors. In a recent article, Sharma et al. (2014) conducted an extensive meta-analytic principal-components analysis and found that questionnaire measures of impulsive personality traits align with three higher-order factors. These findings are consistent with previous reports by this group (Sharma, Kohl, Morgan, & Clark, 2013) and have contributed to a shift within the field of personality and individual difference research toward a model of impulsive personality traits with three superordinate factors (Cross, Copping, & Campbell, 2011; Duckworth & Kern, 2011; King, Patock-Peckham, Dager, Thimm, & Gates, 2014).

As described by Sharma et al. (2014), the first of these factors commonly is labeled as Neuroticism/Negative Emotionality (N/NE) and is associated with a proneness toward psychological distress and a disposition to act rashly in the face of negative emotions. The N/NE factor is theorized to be strongly related to the behavioral inhibition system, resulting in a predisposition to avoid aversive stimuli and engage in impulsive behaviors that are negatively reinforcing. The second factor is labeled Extraversion/Positive Emotionality (E/PE) and is associated with measures of sensation and novelty seeking as well as reward sensitivity. The E/PE factor is theorized to be strongly related to the behavioral activation system and results in a tendency to approach rewarding stimuli as well as a propensity to engage in impulsive behaviors that are positively reinforcing. The third and final factor is labeled Disinhibition versus Constraint/Conscientiousness (DvC/C) and broadly measures a general inability to engage in planned and thoughtful action, persevere on difficult or monotonous tasks, and maintain inhibitory control.

Because the analysis by Sharma et al. (2014) included broad measures of personality traits that contain impulsive features as well as specific measures of impulsigenic traits, the superordinate factors described above are best conceptualized as being three distinct personality traits that contain unique manifestations of impulsive behavior. For example, negative urgency, a specific impulsigenic trait characterized by a tendency to act rashly in the face of negative emotions, is a facet of impulsivity that is most highly associated with neuroticism, a broad personality trait characterized by a proneness toward psychological distress (Whiteside & Lynam, 2001). Thus, although both negative urgency and neuroticism align with the N/NE factor, neuroticism is a composite measure of several characteristics that encompass, but do not solely assess, impulsivity (Sharma et al., 2014). Accordingly, although we refer to the N/NE, E/PE, and DvC/C factors as distinct domains of questionnaire measures of impulsivity throughout the article, these factors should be considered broad personality traits that underlie specific types of impulsive behaviors.

Despite the advancements in clarifying the hierarchical structure of impulsive personality traits, there remain several weaknesses in the assessment of impulsive personality traits using questionnaire measures (McDonald, 2008; Stone et al., 1999). For instance, questionnaire measures require respondents to self-report their own feelings, thoughts, and behaviors and thus require a certain level of insight and are subject to demand effects, which have been suggested to limit the face validity of such measures (Haeffel & Howard, 2010; Moskowitz, 1986; Nisbett & Wilson, 1977). However, few studies have systematically assessed this issue (McCambridge, de Bruin, & Witton, 2012). Additionally, because questionnaire measures determine trait levels of impulsivity through the aggregated assessment of impulsive behaviors over time, they are limited in their ability to predict state occurrences of impulsive action and are not well suited for research aimed at uncovering the cognitive processes underlying specific impulsive behaviors (Cyders & Coskunpinar, 2011).

Behavioral Task Measures of Impulsivity

Behavioral task measures of impulsivity address many of the major weaknesses of questionnaire measures of impulsivity by capturing behavioral manifestations of impulsive traits. Behavioral task measures of impulsivity assess behavioral responses to controlled laboratory paradigms, providing a measurement of state variability in impulsive action that is thought to be reflective of underlying trait characteristics. Because behavioral task measures do not require respondents to report how they act over time or across situations, they eliminate many of the psychometric challenges associated with questionnaire measures and instead offer an objective assessment of impulsive behavior. Moreover, behavioral task measures of impulsivity are specifically designed for use in neuropsychological research, allowing for more effective detection of the neural factors that influence task performance.

Similar to the structural organization of questionnaire measures of impulsivity, research on behavioral task measures of impulsivity also have suffered from a lack of conceptual agreement. Although some neuropsychologists have argued for a classificatory scheme in which behavioral task measures of impulsivity are divided into two broad categories reflecting impulsive choice and impulsive responding (Dalley, Everitt, & Robbins, 2011; Hamilton et al., 2015), others have championed a model in which behavioral task measures can be divided into three domains of executive functioning that assess the ability to shift between mental sets or tasks, update and monitor working memory contents, and inhibit prepotent responses (Miyake et al., 2000). However, Sharma et al. (2014) found the explanatory power of these models to be limited. Instead, the authors found that behavioral task measures of impulsivity align with four higher order factors. The first of these factors is labeled Inattention and measures a general capacity to engage in selective attention by using tasks that require respondents to selectively attend to a target stimulus while suppressing a distractor stimulus. The second factor is labeled Inhibition and provides a measure of overall ability to inhibit behavioral impulses by using tasks that require respondents to selectively respond to target stimuli while suppressing prepotent motor responses. The third factor is labeled impulsive decision-making and assesses both a broad tendency to make risky decisions and a general inability to tolerate reinforcement delays through the use of tasks that require respondents either to earn larger rewards at increasing risk of loss or to select between small, immediate rewards and larger, delayed rewards. The fourth and final factor is labeled set-shifting and provides a measure of cognitive flexibility by using tasks that require respondents to change their approach to a given exercise by resisting memory intrusions of no longer relevant information.

Although the advantages of behavioral task measures of impulsivity have contributed to their growing popularity among personality and individual difference researchers, they also are accompanied by several notable limitations. Behavioral task measures often lack specificity and measure multiple concurrent processes, such as impulsivity, memory, attention, and concentration, making it difficult to disentangle what cognitive factors are influencing performance (Dougherty, Marsh, & Mathias, 2002). Moreover, behavioral task measures only assess a snapshot of impulsive behavior under constrained circumstances. Thus, the generalizability of behavioral task measures to naturalistic settings is unclear. Finally, behavioral task measures are sensitive to environmental effects, which can limit their reliability. However, a recent systematic review documented comparable test–retest reliability between questionnaire and behavioral task measures of impulsivity (Vainik et al., 2013).

Associations Between Questionnaire and Behavioral Task Measures of Impulsivity

Researchers often use questionnaire and behavioral task measures of impulsivity interchangeably under the supposition that they are measuring the same broad trait. However, it has long been speculated that measures of impulsivity are subject to both the jingle and jangle fallacies, which respectively refer to the erroneous assumption that two different constructs are the same because they share the same name or that two identical constructs are distinct because they are labeled differently. Indeed, recent psychometric reports have confirmed this suspicion by documenting weak (Cyders & Coskunpinar, 2011; Lane, Cherek, Rhoades, Pietras, & Tcheremissine, 2003; Reynolds et al., 2006) to moderate (Duckworth & Kern, 2011) convergence between questionnaire and behavioral task measures of impulsivity. This limited overlap between questionnaire and behavioral task measures of impulsivity indicates that measurement constructs commonly labeled as impulsivity actually comprise a multitude of related but distinct impulsigenic traits and further substantiates a need to clarify how these traits uniquely contribute to health outcomes.

Scope of the Present Study

Given the disparate use of questionnaire and behavioral task measures of impulsivity across the obesity literature, the relationship between impulsivity and obesity may depend both on the type of impulsivity measure used and the specific domain of impulsivity assessed. In support of this proposition, a recent systematic review qualitatively found that behavioral task measures of impulsivity sensitive to executive function and food motivation provided the most robust and reliable associations between impulsivity and body weight status among adult samples (Vainik et al., 2013), and a meta-analytic review quantitatively demonstrated that behavioral task measures of impulsivity were stronger predictors of the association between impulsivity and pediatric obesity than were questionnaire measures (Thamotharan et al., 2013). Thus, there is initial evidence to suggest that questionnaire and behavioral task measures of impulsivity are differentially associated with obesity in both adult and pediatric samples. However, there remains a need to synthesize the voluminous research linking impulsivity to obesity in adult populations and to determine whether the association between impulsivity and obesity varies as a function of how impulsivity is measured. Accordingly, the present meta-analysis aimed to quantitatively assess whether common types of impulsivity measures, defined as questionnaire versus behavioral task measures of impulsivity, are differentially associated with BMI among adult populations and to determine which specific domains of impulsivity, conceptualized according to the factor structure found by Sharma et al. (2014), are most highly related to BMI.

Method

Study Selection

Because obesity most commonly is assessed using BMI (Welborn & Dhaliwal, 2007), we selected articles that included measures of both impulsivity and BMI. Articles were identified for inclusion through electronic databases, including PubMed, Google Scholar, and PsycINFO, using relevant search terms. Search terms were based on previous quantitative and qualitative reviews (Fitzpatrick et al., 2013; Jokela et al., 2013; Sharma et al., 2014; Thamotharan et al., 2013; Vainik et al., 2013) as well as terminology common to the impulsivity and obesity literatures. Specifically, the terms *impuls**, *self-control*, *inhibitory control*, *self-reg**, *executive function*, *personality*, *behavioral inhibition*, *emotion reg**, *body mass*, *body weight*, *overweight*, and *obes** were chosen. In an effort to further identify studies that utilized validated measures of impulsivity, searches also were conducted using the specific names of questionnaire and behavioral task measures of impulsivity and their respective subscales. Because we organized the measures of impulsivity included in the present-analysis according to the factor structure found by Sharma et al. (2014), we were interested in including measures of impulsivity that were similar to those utilized in their analysis. As such, we restricted our search terms to general measures of impulsivity that were consistent with or related to those used in the study by Sharma et al. (2014) rather than measures specifically focused on eating- or food-related impulsivity. These included *Delay Discounting, Go/No-Go*, *Iowa Gambling Task*, *Wisconsin Card Sort Task, Stop Signal Task*, S*top Signal Reaction Time*, *Immediate Memory*, *Delayed Memory*, *Matching Familiar Figures Task*, *Stroop Task*, *Balloon Analogue Risk Task*, *Big Five Inventory*, *Eysenck Personality Inventory*, *Eysenck Personality Questionnaire*, *NEO*, *Neuroticism*, *Barratt Impulsiveness Scale*, *UPPS*, *Negative Urgency*, *Behavioral Inhibition System*, *Behavioral Activation System*, *Multidimensional Personality Questionnaire*, and *Dickman Impulsiveness Inventory*. Once an initial body of literature was identified, searches were conducted using the reference lists from related articles. In addition, e-mail alerts and forward searches were utilized. These search strategies included articles published during or before 2015, resulting in a total of 27,150 articles identified (see Figure 1).

Based on titles and abstracts of the articles identified through our initial search, we included 1,413 articles that reported content related to impulsivity or BMI. After removal of duplicate articles ($n = 379$), the remaining 1,034 articles were screened according to the inclusion and exclusion criteria described below.

Inclusion and Exclusion Criteria

Articles were included if they (a) contained at least one standard questionnaire or behavioral task measure of impulsivity that was not eating- or food-related; (b) had a measure of BMI; (c) sampled from human subjects 18 years of age or older; (d) included a healthy sample free from clinical conditions known to impair executive functioning (i.e., eating disorders, diabetes, and traumatic brain injury); (e) included baseline data if a longitudinal study design was used; (f) had a minimum sample size of 20; (g) were published or available in English; (h) included original data that was peer-reviewed; (i) presented data in a form that could be converted into a standard measure of effect size and variance; and (j) reported the sample size used in the computation of each convertible statistic. For articles that provided insufficient infor-

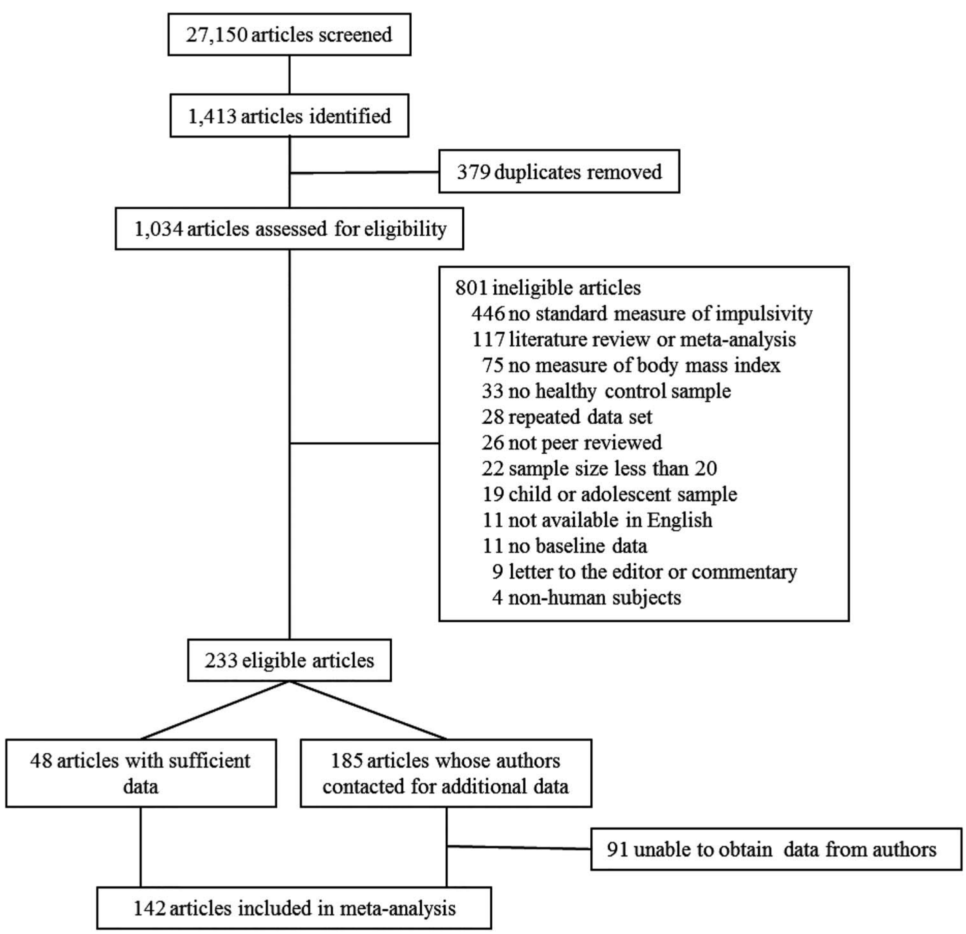

Figure 1. Flowchart of study inclusion.

mation to determine eligibility or to compute the effect sizes of interest ($n = 185$), study authors were contacted to obtain the necessary data. Of the study authors contacted, 51% ($n = 94$) provided the information needed to compute effect sizes.

As shown in Figure 1, the final body of literature was comprised of 142 articles. Of these articles, 77% ($n = 110$) were published in 2010 or later, 20% ($n = 28$) were published between 2000 and 2009, and 3% ($n = 4$) were published between 1990 and 1999.

Coding Procedures

The effect sizes extracted from the included articles were independently coded on two occasions by the first author. In addition, two trained raters coded each of the moderator variables described below from a random sampling of 20% ($n = 28$) of the included articles. Interrater reliability was high both for effect sizes ($\kappa = 0.87$) and for moderator variables (κs > 0.81). All conflicts between raters were resolved by discussion and reexamination of the articles in question.

Coding of descriptive and moderator variables. For each article, the following variables were coded: (a) the type of study design used (cross-sectional, longitudinal, treatment trial, or experimental laboratory study); (b) whether a primary focus of the study was to assess the relationship between impulsivity and BMI (yes or no); (c) the geographic location of data collection (United States, Canada, Europe, Russia, Australia/New Zealand, Asia, Africa, Central/South America, Middle East, mixed, or not reported); (d) whether participants were seeking weight loss treatment (yes, no, or mixed sample); (e) the age (mean and standard deviation) of the sample; (f) the total number of male and female participants; (g) the BMI (mean and standard deviation) of the sample; (h) whether BMI was calculated using self-reported or objectively measured height and weight, and, as described more fully below; and (i) the name, type, and domain of impulsivity measure used.

To determine whether the type of impulsivity measure used influences the association between impulsivity and BMI, impulsivity measures broadly were coded as being either a questionnaire or behavioral task measure of impulsivity. To further test whether specific domains of impulsivity differentially relate to BMI, impulsivity measures also were categorized according to findings from a recent meta-analytic principal-components analysis (Sharma et al., 2014). Results from the article by Sharma et al. (2014) showed that questionnaire measures of impulsivity align with three higher order factors (i.e., N/NE, E/PE, and DvC/C) whereas behavioral task measures of impulsivity align with four higher order factors (i.e., Inattention, Inhibition, Impulsive Decision-Making, and Set-Shifting). Each impulsivity measure included in the present study was coded according to this factor structure. In total, 55 impulsivity measures (38 questionnaire measures and 17 behavioral task measures) were included. Of these, 22 impulsivity measures (14 questionnaire measures and 8 behavioral task measures) were not included in the analysis by Sharma et al. (2014). For impulsivity measures that were not examined by Sharma et al. (2014), we used descriptions of the measures and known empirical correlations to categorize the measures into the most appropriate domain. Importantly, there were no differences in effect sizes between impulsivity measures that were and were not included in the analysis conducted by Sharma et al. (2014) for any of the domains of impulsivity assessed (ps > 0.15). Tables 1 and 2, respectively, provide an overview of how questionnaire and behavioral task measures of impulsivity were coded as well as a description of each measure.

Computation of effect sizes. Effect sizes consisted of Fisher's z-transformed correlation coefficients. If studies reported effects using other convertible statistics (e.g., t tests, chi-square tests, or comparable means with standard deviations), they were transformed into correlation coefficients using formulas provided by Lipsey and Wilson (2001). Data were coded so that higher values indicated greater impulsivity and BMI. Numerous studies reported results from more than one measure of impulsivity within the same sample. Given that the inclusion of multiple outcomes within a single sample violates the assumption of independence between effects, we followed procedures outlined by Borenstein, Hedges, Higgins, and Rothstein (2009) to correct for this issue. First, multiple effect sizes from the same sample were aggregated to produce one effect size per sample. Second, the correlations between multiple measures of impulsivity within the same sample were accounted for in the computation of the variance for the aggregated effect size to adjust for covariance within samples. In Table 3, correlations are reported for individual impulsivity measures as well as the average correlation for all of the impulsivity measures used in each study. An excel file of Table 3 has been included as supplemental material to allow for open access to the data (see Table S1).

Analytic Strategy

The systems described by Hedges and Olkin (1985) and Lipsey and Wilson (2001) were followed to quantitatively synthesize the relationship between impulsivity and BMI. Specifically, the z-transformed correlation coefficients were weighted by the inverse of the variance to establish the grand mean estimate of the overall relationship between impulsivity and BMI. The estimated average correlation was then obtained through a z-to-r transformation of the effect size estimate, and a forest plot was constructed to graphically display the overall weight of each study included in the analysis (Neyeloff, Fuchs, & Moreira, 2012). Confidence intervals and tests of heterogeneity were calculated.

The Cochran's Q test and I^2 index were used to examine heterogeneity in the overall relationship between impulsivity and BMI. The Q statistic provides information on whether the variability among the reported effect sizes across studies is greater than what is likely to have resulted from sampling error alone (Lipsey & Wilson, 2001) whereas the I^2 value provides the percentage of total variability among correlations caused by true heterogeneity rather than by sampling error alone (Huedo-Medina, Sánchez-Meca, Marín-Martínez, & Botella, 2006). After determining whether the overall association between impulsivity and BMI was heterogeneous, moderation analyses were conducted.

Moderation analyses with categorical predictors were analyzed using the between-groups heterogeneity (Q_B) analysis, which is the meta-analytic equivalent of analysis of variance. For categorical predictors with more than two groups, pairwise comparisons were computed. Moderation analyses with continuous predictors were analyzed using weighted least squares regression analysis (Lipsey & Wilson, 2001). A mixed-effects modeling approach to signifi-

Table 1
Comprehensive List of Questionnaire Measures of Impulsivity Included in the Present Meta-Analysis

Measure	Subscale	Description
Disinhibition versus Constraint/Conscientiousness		
BFI*	Conscientiousness	9-item subscale measuring a tendency to be thorough, careful, and vigilant. Individuals respond to questions using a 5-point Likert scale, with lower scores indicating higher impulsivity.
BIS	Motor impulsivity	11-item subscale measuring a tendency to act rashly and to have difficulty maintaining a consistent lifestyle. Individuals respond to questions using a 4-point Likert scale, with higher scores indicating higher impulsivity.
BIS	Nonplanning impulsivity	11-item subscale measuring a tendency to have difficulty engaging both in careful planning and challenging mental tasks. Individuals respond to questions using a 4-point Likert scale, with higher scores indicating higher impulsivity.
DII	Dysfunctional impulsivity	12-item subscale measuring a tendency to act with little forethought under problematic circumstances. Individuals respond to true or false questions, with higher scores indicating higher impulsivity.
I7	Impulsivity	19-item subscale measuring impulsive tendencies and behaviors. Individuals respond to yes or no questions, with higher scores indicating higher impulsivity
IPIP*	Conscientiousness	10-item subscale measuring a tendency to be thorough, careful, and vigilant. Individuals respond to questions using a 5-point Likert scale, with lower scores indicating higher impulsivity.
MPQ	Constraint	77-item subscale measuring a tendency to exhibit self-control, caution, and avoidance of danger. Individuals respond to true or false questions, with lower scores indicating higher impulsivity.
NEO-PI-R	Conscientiousness	48-item subscale measuring a tendency to be thorough, careful, and vigilant. Individuals respond to questions using a 5-point Likert scale, with lower scores indicating higher impulsivity.
UPPS	(Lack of) Perseverance	10-item subscale measuring a tendency to have difficulty remaining focused on boring or challenging tasks. Individuals respond to questions using a 4-point Likert scale, with higher scores indicating higher impulsivity.
UPPS	(Lack of) Premeditation	11-item subscale measuring a tendency to act rashly without regard to consequences. Individuals respond to questions using a 4-point Likert scale, with higher scores indicating higher impulsivity.
Extraversion/Positive Emotionality		
BFI*	Extraversion	8-item subscale measuring a tendency to be outgoing and energetic. Individuals respond to questions using a 5-point Likert scale, with higher scores indicating higher impulsivity.
BIS/BAS	Behavioral inhibition system	7-item subscale measuring a tendency to avoid situations with aversive consequences. Individuals respond to questions using a 4-point Likert scale, with higher scores indicating higher impulsivity.
BIS/BAS	Drive	4-item subscale measuring a tendency to persistently pursue desired goals. Individuals respond to questions using a 4-point Likert scale, with higher scores indicating higher impulsivity.
BIS/BAS	Fun-seeking	4-item subscale measuring a tendency to desire rewards and to approach potentially rewarding events without forethought. Individuals respond to questions using a 4-point Likert scale, with higher scores indicating higher impulsivity.
BIS/BAS	Reward responsiveness	4-item subscale measuring a tendency to have high sensitivity to rewards. Individuals respond to questions using a 4-point Likert scale, with higher scores indicating higher impulsivity.
DII	Functional impulsivity	11-item subscale measuring a tendency to act with little forethought under beneficial circumstances. Individuals respond to true or false questions, with higher scores indicating higher impulsivity.
EPP*	Impulsivity	20-item subscale measuring a tendency to act without forethought and engage in unpredictable behavior. Individuals respond to questions using a 3-point Likert scale, with higher scores indicating higher impulsivity.
EPQ	Extraversion	23-item subscale measuring a tendency to be outgoing and energetic. Individuals respond to yes or no questions, with higher scores indicating higher impulsivity.
IPIP*	Extraversion	10-item subscale measuring a tendency to be outgoing and energetic. Individuals respond to questions using a 5-point Likert scale, with higher scores indicating higher impulsivity.
KSP*	Impulsiveness	10-item subscale measuring a tendency to act with little forethought and a preference for speed rather than accuracy. Individuals respond to questions using a 4-point Likert scale, with higher scores indicating higher impulsivity.

(*table continues*)

Table 1 (*continued*)

Measure	Subscale	Description
MPQ	Positive emotionality	89-item subscale measuring a tendency to be positively engaged in interpersonal relationships and to experience positive mood states. Individuals respond to true or false questions, with higher scores indicating higher impulsivity.
NEO-PI-R	Extraversion	48-item subscale measuring a tendency to be outgoing and energetic. Individuals respond to questions using a 5-point Likert scale, with higher scores indicating higher impulsivity.
SPSRQ*	Sensitivity to punishment	24-item subscale measuring a tendency to have a low tolerance for monotony and to avoid situations with aversive consequences. Individuals respond to yes or no questions, with higher scores indicating higher impulsivity.
SPSRQ*	Sensitivity to reward	24-item subscale measuring a tendency to have a high sensitivity to rewards and a preference to engage in rewarding activities. Individuals respond to yes or no questions, with higher scores indicating higher impulsivity.
TCI*	Novelty seeking	40-item subscale measuring a tendency to experience intense excitement in the presence of novel stimuli. Individuals respond to questions using a 5-point Likert scale, with higher scores indicating higher impulsivity.
UPPS	Positive urgency	14-item subscale measuring a tendency to act rashly in the face of positive emotions. individuals respond to questions using a 4-point Likert scale, with higher scores indicating higher impulsivity.
UPPS	Sensation seeking	12-item subscale measuring a tendency to take risks and engage in dangerous activities. Individuals respond to questions using a 4-point Likert scale, with higher scores indicating higher impulsivity.
Neuroticism/Negative Emotionality		
BFI*	Neuroticism	8-item subscale measuring a proneness towards psychological distress. Individuals respond to questions using a 5-point Likert scale, with higher scores indicating higher impulsivity.
BIS	Attentional impulsivity	8-item subscale measuring a tendency to have difficulty focusing on tasks and to experience intrusive and racing thoughts. Individuals respond to questions using a 4-point Likert scale, with higher scores indicating higher impulsivity.
DERS*	Impulse	6-item subscale measuring a tendency to act rashly in the face of negative emotions. Individuals respond to questions using a 5-point Likert scale, with higher scores indicating higher impulsivity.
DPQ*	Neuroticism	21-item subscale measuring a proneness towards psychological distress. Individuals respond to questions using a 3-point Likert scale, with higher scores indicating higher impulsivity.
EPI	Neuroticism	24-item subscale measuring a proneness towards psychological distress. Individuals respond to yes or no questions, with higher scores indicating higher impulsivity.
EPQ	Neuroticism	24-item subscale measuring a proneness towards psychological distress. Individuals respond to yes or no questions, with higher scores indicating higher impulsivity.
IPIP*	Neuroticism	10-item subscale measuring a proneness towards psychological distress. Individuals respond to questions using a 5-point Likert scale, with higher scores indicating higher impulsivity.
MPI*	Neuroticism	24-item subscale measuring a proneness towards psychological distress. Individuals respond to questions using a 3-point Likert scale, with higher scores indicating higher impulsivity.
MPQ	Negative emotionality	62-item subscale measuring a tendency to be negatively engaged in interpersonal relationships and to experience anxiety, anger, and worry. Individuals respond to true or false questions, with higher scores indicating higher impulsivity.
NEO-PI-R	Neuroticism	48-item subscale measuring a proneness towards psychological distress. Individuals respond to questions using a 5-point Likert scale, with higher scores indicating higher impulsivity.
UPPS	Negative urgency	12-item subscale measuring a tendency to act rashly in the face of negative emotions. Individuals respond to questions using a 4-point Likert scale, with higher scores indicating higher impulsivity.

Note. Measures marked with an asterisk were not included in the meta-analytic principal-components analysis by Sharma et al. (2014). Descriptions of these measures and known empirical correlations were used to categorize them into the most appropriate domain. BFI = Big Five Inventory; BIS = Barratt Impulsiveness Scale; BIS/BAS = Behavioral Inhibition System/Behavioral Activation System; DERS = Difficulties in Emotion Regulation Scale; DII = Dickman Impulsiveness Inventory; DPQ = Dutch Personality Questionnaire; EPI = Eysenck Personality Inventory; EPP = Eysenck Personality Profiler; EPQ = Eysenck Personality Questionnaire; I7 = Eysenck Impulsiveness Questionnaire; IPIP = International Personality Item Pool; KSP = Karolinska Scales of Personality; MPI = Maudsley Personality Inventory; MPQ = Multidimensional Personality Questionnaire; NEO-PI-R = NEO Personality Inventory-Revised; SPSRQ = Sensitivity to Punishment and Sensitivity to Reward Questionnaire; TCI = Temperament and Character Inventory; UPPS = UPPS Impulsive Behavior Scale.

Table 2
Comprehensive List of Behavioral Task Measures of impulsivity Included in the Present Meta-Analysis

Task	Measure/subscale	Description
Inattention		
Stroop	Error	Task in which individuals are required to name the color of a written color word while inhibiting the impulse to read the word itself. The total number of errors made provides a measure of inhibitory control, with higher scores indicating higher impulsivity.
Stroop*	Interference	Task in which individuals are required to name the color of a written color word while inhibiting the impulse to read the word itself. The difference between mean response times of correct responses on incongruent and control trials provides a measure of inhibitory control, with lower scores indicating higher impulsivity.
Inhibition		
CPT*	Commission errors	Task in which stimuli are presented continuously and individuals must make a motor response for the go stimulus and withhold a motor response for the no-go stimulus. The number of responses made following a no-go stimulus provides a measure of attention, with higher scores indicating higher impulsivity.
CGT*	Quality of decision making	Task in which individuals bet on the location of a token hidden behind one of two colored boxes. The average proportion of trials where the correct outcome is selected provides a measure of decision making quality, with lower scores indicating higher impulsivity.
GNG*	Reaction time	Task in which stimuli are presented continuously and individuals must make a motor response for the go stimulus and withhold a motor response for the no-go stimulus. Reaction times on correct trials provide a measure of inhibitory control, with higher scores indicating higher impulsivity.
GNG	Inhibition	Task in which stimuli are presented continuously and individuals must make a motor response for the go stimulus and withhold a motor response for the no-go stimulus. The proportion of no-go targets in which an individual successfully withheld a motor response provides a measure of inhibitory control, with lower scores indicating higher impulsivity.
IGT	Net score	Task in which individuals select cards from advantageous and disadvantageous decks to maximize monetary profit over loss. The difference between the total number of disadvantageous and advantageous cards selected provides a measure of decision making under uncertainty, with lower scores indicating higher impulsivity.
IGT	Percent advantageous cards	Task in which individuals select cards from advantageous and disadvantageous decks to maximize monetary profit over loss. The difference between the total number of disadvantageous and advantageous cards provides a measure of decision making under uncertainty, with lower scores indicating higher impulsivity.
MFFT	Error	Task in which individuals are required to match a target picture with the identical image in an array of six highly similar pictures. The number of errors provides a measure of reflectivity, with higher scores indicating higher impulsivity.
Impulsive Decision-Making		
BART	Average adjusted number of pumps	Task in which individuals are presented with a series of balloons and offered the chance to earn money by pumping the balloons, with the chance that the balloon might explode with each pump. The average number of pumps on unexploded balloons provides a measure of risk-taking behavior, with higher scores indicating higher impulsivity.
CFCS*	Total score	14-item scale measuring a tendency to consider future consequences. Individuals respond to questions using a 5-point Likert Scale, with lower scores indicating greater impulsivity.
DDT	Indifference point	Task in which individuals choose between smaller, immediate rewards and larger, delayed rewards. The point at which the delayed reward is equally as valuable as the immediate reward provides a measure of impulsive decision making, with higher scores indicating higher impulsivity.
MCQ*	Indifference point	27-item scale measuring a preference for smaller, immediate rewards or larger, delayed rewards. Individuals are presented with a series of immediate and delayed rewards of varying monetary value from which a discounting rate is calculated, with higher scores indicating higher impulsivity.
SST	Stop signal reaction time	Task in which individuals respond on a keyboard as quickly as possible when a go stimuli appears on a computer screen and inhibit their responses when an auditory stop signal is heard. The difference between the mean stop delay and the mean reaction time on go trials provide a measure of inhibitory control, with higher scores indicating higher impulsivity.
ZTPI*	Future	13-item scale measuring a tendency to consider future consequences. Individuals respond to questions using a 5-point Likert scale, with lower scores indicating greater impulsivity.
Set-Shifting		
WCST*	Categories completed	Task in which individuals have to match a target card with one of four category cards under changing conditions. The number of categories completed provides a measure of set-shifting behavior, with lower scores indicating higher impulsivity.
WCST	Perseverative errors	Task in which individuals have to match a target card with one of four category cards under changing conditions. The number of incorrect responses that would have been correct for the preceding condition provides a measure of set-shifting behavior and reversal learning, with higher scores indicating higher impulsivity.

Note. Measures marked with an asterisk were not included in the meta-analytic principal-components analysis by Sharma et al. (2014). Descriptions of these measures and known empirical correlations were used to categorize them into the most appropriate domain. BART = Balloon Analogue Risk Task; CFCS = Consideration of Future Consequences Scale; CGT = Cambridge Gambling Task; CPT = Continuous Performance Test; DDT = Delay Discounting Task; GNG = Go/No-Go Task; IGT = Iowa Gambling Task; MCQ = Monetary Choice Questionnaire; MFFT = Matching Familiar Figures Task; SST = Stop Signal Task; Stroop = Stroop Color-Word Test; WCST = Wisconsin Card Sort Task; ZTPI = Zimbardo Time Perspective Inventory.

Table 3
Summary of Included Studies

Authors	Year	*N*	Age Mean	Age *SD*	BMI Mean	BMI *SD*	Impulsivity measure(s)	ES (*r*)	Average ES (*r*)
1. Abilés et al.	2010	75	39.53	9.88	41.33	13.88	EPQ Neuroticism	.31	.31
2. Acheson et al.	2007	20	24.60	6.80	23.44	1.39	BART Average Adjusted Number of Pumps	.340	.04
							SST Stop Signal Reaction Time	−.26	
3. Adams et al.	2009a	404	34.70	12.00	25.70	6.40	IPIP Conscientiousness	.06	.07
							IPIP Extraversion	−.02	
							IPIP Neuroticism	.03	
							CFCS Total Score	.18	
							DDT Indifference Point	.13	
							ZTPI Future	.07	
4. Adams et al.	2009b	804	50.50	18.10	26.20	5.00	CFCS Total Score	.14	.14
5. Alexopoulos et al.	2010	100	22.80	4.60	22.60	2.95	Stroop Error	.12	.12
6. Allan et al.	2010	62	20.40	7.10	22.60	2.40	Stroop Interference	.30	.30
7. Allan et al.	2011	50	22.00	4.90	—	—	GNG Reaction Time	−.14	−.14
8. Allom et al.	2014	115	19.79	1.95	21.96	3.10	SST Stop Signal Reaction Time	.02	.05
							Stroop Interference	.08	
9. Allom et al.	2015	82	20.43	4.86	22.62	2.64	Stroop Interference	−.08	−.08
10. Allom et al.	2015	78	22.97	5.81	23.11	2.56	Stroop Interference	.19	.19
11. Aloi et al.	2015	45	25.60	3.50	20.20	1.60	IGT Net Score	−.14	−.05
							WCST Perseverative Errors	.04	
12. Ambwani et al.	2014	734	19.75	1.55	23.43	4.16	DERS Impulse	.02	.02
13. Appelhans et al.	2012	78	32.40	8.10	32.10	3.90	BIS Attentional Impulsivity	−.18	−.05
							BIS Motor Impulsivity	−.08	
							BIS Nonplanning Impulsivity	−.06	
							DDT Indifference Point	.12	
14. Ariza et al.	2012	84	30.74	6.74	30.19	4.78	Stroop Interference	.10	.03
							WCST Perseverative Errors	−.04	
15. Armon et al.	2013	1492	47.57	9.72	26.67	3.90	BFI Conscientiousness	.04	.08
							BFI Extraversion	.11	
							BFI Neuroticism	.08	
16. Atherton et al.	2014	225,217	34.50	13.53	24.90	5.70	BFI Conscientiousness	.01	.01
							BFI Extraversion	.01	
							BFI Neuroticism	−.001	
17. Babbs et al.	2013	26	24.35	1.34	26.76	.98	BIS Attentional Impulsivity	.28	.33
							BIS Motor Impulsivity	.27	
							BIS Nonplanning Impulsivity	.44	
18. Benford et al.	2014	509	25.18	8.28	24.01	4.90	NEO-PI-R Conscientiousness	−.19	−.01
							NEO-PI-R Extraversion	.11	
							NEO-PI-R Neuroticism	.04	
19. Bickel et al.	2014	1,181	31.78	11.25	—	—	DDT Indifference Point	.12	.12
20. Boisseau et al.	2013	21	24.24	3.47	22.22	2.28	IGT Net Score	−.10	−.10
21. Bongers et al.	2014	319	34.29	7.82	31.53	4.27	DDT Indifference Point	.08	.02
							SST Stop Signal Reaction Time	−.04	
22. Booth et al.	2013	627	72.66	.72	27.60	4.22	IPIP Conscientiousness	.10	.06
							IPIP Extraversion	.04	
							IPIP Neuroticism	.03	
23. Brockmeyer et al.	2014	89	29.31	6.88	25.88	2.62	DERS Impulse	.14	.14
24. Brogan et al.	2011	92	49.58	13.86	32.16	6.24	IGT Net Score	.29	.29
25. Brummett et al.	2006	3,401	42.90	1.70	23.00	4.00	NEO-PI-R Conscientiousness	.09	.07
							NEO-PI-R Extraversion	.06	
							NEO-PI-R Neuroticism	.06	
26. Buchholz et al.	2014	206	19.50	3.01	23.00	4.54	I7 Impulsivity	−.03	−.03
27. Calvo et al.	2014	62	21.13	2.31	28.77	3.90	GNG Reaction Time	.35	.35
28. Canetti et al.	2009	102	38.50	10.75	40.25	7.45	NEO-PI-R Neuroticism	−.15	−.15
29. Capuron et al.	2011	101	37.80	11.20	48.80	9.20	NEO-PI-R Extraversion	−.13	−.07
							NEO-PI-R Neuroticism	−.01	
30. Chabris et al.	2008	126	30.40	10.30	28.90	7.30	DDT Indifference Point	.28	.28
31. Chabris et al.	2008	103	26.10	10.10	24.50	4.90	DDT Indifference Point	.24	.24
32. Chabris et al.	2008	326	31.40	9.00	25.10	5.60	DDT Indifference Point	.18	.18
33. Chan et al.	2014	64	25.45	6.70	20.58	1.78	BIS Attentional Impulsivity	.15	.01
							BIS Motor Impulsivity	.02	
							BIS Nonplanning Impulsivity	−.08	

(*table continues*)

Table 3 (*continued*)

Authors	Year	*N*	Age Mean	Age *SD*	BMI Mean	BMI *SD*	Impulsivity measure(s)	ES (*r*)	Average ES (*r*)
							IGT Net Score	−.07	
34. Chang et al.	2015	4,264	22.20	5.00	22.06	3.54	MPI Neuroticism	−.07	−.07
35. Christian et al.	2011	250	63.80	13.70	28.30	6.30	NEO-PI-R Neuroticism	.04	.04
36. Cloninger et al.	2007	503	45.73	14.72	32.41	5.42	TCI Novelty Seeking	.18	.18
37. Cooper et al.	2014	251	19.46	1.66	21.85	4.41	DERS Impulse	.09	.09
38. Crockett et al.	2015	544	19.25	2.15	23.67	3.80	DERS Impulse	.06	.06
39. Dahl et al.	2012	109	41.10	10.40	47.20	5.80	EPQ Neuroticism	.21	.21
40. Dalle et al.	2013	771	47.58	10.02	34.50	5.35	TCI Novelty Seeking	.03	.03
41. Daniel et al.	2013	48	24.91	4.68	26.82	3.23	ZTPI Future	.09	.10
							BIS/BAS Behavioral Inhibition System	.20	
							BIS/BAS Drive	.10	
							BIS/BAS Fun-Seeking	.10	
							BIS/BAS Reward Responsiveness	.01	
42. Danner et al.	2012	67	39.29	13.82	25.52	2.34	BIS/BAS Behavioral Inhibition System	.23	.14
							BIS/BAS Drive	−.004	
							BIS/BAS Fun-Seeking	.06	
							BIS/BAS Reward Responsiveness	.14	
							IGT Net Score	.25	
43. Danner et al.	2013	34	30.19	14.50	21.83	2.30	BIS Attentional Impulsivity	−.06	−.06
							BIS Motor Impulsivity	−.05	
44. Dao et al.	2013	152	69.44	2.91	26.49	4.52	Stroop Interference	−.02	−.02
45. Dassen et al.	2015	151	31.50	11.52	25.90	5.90	CFCS Total Score	.01	.13
	2015	151	31.50	11.52	25.90	5.90	MCQ Indifference Point	.24	
46. Davis et al.	1993	100	21.20	2.50	21.60	2.50	EPI Neuroticism	−.05	−.05
47. Davis et al.	1997	191	21.69	3.07	22.89	4.46	EPQ Neuroticism	−.02	−.02
48. Davis et al.	2007	151	33.50	7.10	27.60	5.90	SPSRQ Sensitivity to Reward	.00	.00
49. Davis et al.	2008	111	34.86	7.03	30.18	5.47	SPSRQ Sensitivity to Punishment	.27	.26
							SPSRQ Sensitivity to Reward	.26	
50. De Panfilis et al.	2008	92	41.80	12.70	38.50	6.30	TCI Novelty Seeking	.10	.10
51. de Zwaan et al.	2015	923	48.52	11.69	29.46	4.10	BIS/BAS Behavioral Inhibition System	.01	−.01
							BIS/BAS Drive	−.04	
							BIS/BAS Fun-Seeking	.03	
							BIS/BAS Reward Responsiveness	−.03	
52. Dietrich et al.	2014	192	26.60	4.70	26.70	6.20	BIS/BAS Behavioral Inhibition System	.06	.06
53. Eiler et al.	2014	48	27.07	5.23	29.01	2.49	UPPS Negative Urgency	.40	.40
54. Elfhag et al.	2008	442	43.70	12.60	40.50	5.30	NEO-PI-R Conscientiousness	.07	.05
							NEO-PI-R Extraversion	−.08	
							NEO-PI-R Neuroticism	.15	
55. Epstein et al.	2014	199	42.70	7.30	27.60	7.30	DDT Indifference Point	.21	.21
56. Fagundo et al.	2012	189	29.12	8.12	26.43	3.98	BIS Attentional Impulsivity	.18	.30
							BIS Motor Impulsivity	.21	
							BIS Nonplanning Impulsivity	.15	
							IGT Net Score	.13	
							Stroop Interference	.23	
							WCST Perseverative Errors	.50	
57. Fassino et al.	2002	141	36.68	8.11	30.58	4.09	TCI Novelty Seeking	.24	.24
58. Fernández-Aranda et al.	2014	189	34.00	12.30	29.40	3.18	TCI Novelty Seeking	.21	.21
59. Fillmore et al.	2006	20	38.30	7.30	25.20	3.00	GNG Inhibition	.06	.06
60. Franken et al.	2005	99	20.20	2.10	21.30	2.60	SPSRQ Sensitivity to Punishment	−.12	.10
							SPSRQ Sensitivity to Reward	.31	
61. Gade et al.	2014	102	42.60	9.80	43.50	4.90	NEO-PI-R Conscientiousness	.24	.13
							NEO-PI-R Extraversion	−.07	
							NEO-PI-R Neuroticism	.21	
62. Gagnon et al.	2010	21	68.43	5.56	24.55	5.00	Stroop Interference	.51	.51
63. Galderisi et al.	2011	77	23.80	3.40	21.50	2.60	TCI Novelty Seeking	−.03	.08
							WCST Perseverative Errors	.18	
64. Garza et al.	2013	172	43.00	13.68	26.70	6.73	DDT Indifference Point	.18	.18
65. Garza et al.	2015	478	42.00	12.00	27.10	6.50	DDT Indifference Point	.21	.21
66. Giesen et al.	2012	82	21.60	.51	23.15	.85	SST Stop Signal Reaction Time	−.03	−.03
67. Grant et al.	2015	207	22.25	3.41	24.25	2.11	CGT Quality of Decision Making	.20	.15

(*table continues*)

Table 3 (*continued*)

Authors	Year	*N*	Age Mean	Age *SD*	BMI Mean	BMI *SD*	Impulsivity measure(s)	ES (*r*)	Average ES (*r*)
							SST Stop Signal Reaction Time	.09	
68. Griva et al.	2014	413	29.50	7.20	24.28	4.92	ZTPI Future	−.03	−.03
69. Guillaume et al.	2010	83	28.00	—	20.20	—	IGT Net Score	−.04	−.04
70. Gunstad et al.	2007	408	38.05	8.53	25.34	2.89	Stroop Error	.23	.23
71. Hall et al.	2012	208	45.21	18.06	—	—	GNG Reaction Time	.19	.18
							Stroop Interference	.16	
72. Hall et al.	2014a	88	19.50	2.35	22.59	3.67	GNG Reaction Time	.09	.06
							Stroop Interference	.02	
73. Hall et al.	2014b	40	74.75	8.20	25.35	4.30	GNG Reaction Time	−.17	−.07
							SST Stop Signal Reaction Time	.11	
							Stroop Interference	−.14	
74. Hall et al.	2014b	79	18.71	1.23	22.41	3.34	GNG Reaction Time	.05	.02
							Stroop Interference	−.02	
75. Harrison et al.	2010	90	28.50	9.93	21.61	1.89	DERS Impulse	.15	.15
76. Hartmann et al.	2015	2,905	57.64	13.69	24.62	3.84	BFI Conscientiousness	.18	.06
							BFI Extraversion	−.02	
							BFI Neuroticism	.02	
77. He et al.	2015	336	20.38	1.00	20.40	2.20	IGT Net Score	.13	.13
78. Hendrawan et al.	2012	32	19.13	1.10	21.37	2.79	Stroop Interference	−.19	−.01
							WCST Categories Completed	.17	
79. Hendrick et al.	2012	43	30.75	10.33	25.64	1.74	SST Stop Signal Reaction Time	−.24	−.24
80. Hendrickson et al.	2013	304	24.58	7.68	27.52	.45	BIS Attentional Impulsivity	.04	−.001
							BIS Motor Impulsivity	−.08	
							BIS Nonplanning Impulsivity	−.01	
							DDT Indifference Point	.04	
81. Hendrickson et al.	2015	69	21.97	5.41	26.25	4.49	MCQ Indifference Point	.12	.20
							DDT Indifference Point	.28	
82. Hermans et al.	2012	85	20.20	1.85	22.38	2.26	SST Stop Signal Reaction Time	.12	.12
83. Hou et al.	2011	42	22.00	4.70	21.75	3.36	BIS Attentional Impulsivity	−.20	−.07
							BIS Motor Impulsivity	−.08	
							BIS Nonplanning Impulsivity	−.09	
							BIS/BAS Reward Responsiveness	−.10	
							SPSRQ Sensitivity to Reward	.11	
84. Houben et al.	2011	29	21.15	1.81	23.12	4.27	SST Stop Signal Reaction Time	.01	.01
85. Houben et al.	2012	50	21.54	3.18	22.52	2.81	SST Stop Signal Reaction Time	−.15	−.15
86. Houben et al.	2014	87	26.17	10.90	22.28	4.34	SST Stop Signal Reaction Time	−.02	−.02
87. Hsieh et al.	2010	53	29.40	9.69	22.46	—	WCST Perseverative Errors	.11	.11
88. Incollingo Belskey et al.	2014	41	54.95	14.36	26.91	2.83	BFI Conscientiousness	−.01	.10
							BFI Extraversion	.15	
							BFI Neuroticism	.17	
							ZTPI Future	.11	
89. Ishizawa et al.	2010	27	36.76	6.90	24.10	2.36	GNG Reaction Time	−.32	−.13
							WCST Perseverative Errors	.07	
90. Jansen et al.	2009	63	19.10	1.30	22.40	2.60	SST Stop Signal Reaction Time	.08	.08
91. Jarmolowicz et al.	2014	100	30.70	10.10	26.35	5.33	BIS/BAS Behavioral Inhibition System	−.17	.03
							BIS/BAS Drive	.01	
							BIS/BAS Fun-Seeking	.05	
							BIS/BAS Reward Responsiveness	−.08	
							MCQ Indifference Point	.33	
92. John et al.	2009	20	26.40	4.04	22.98	3.44	Stroop Interference	.11	.11
93. Kakizaki et al.	2008	30,722	—	—	23.63	2.93	EPQ Extraversion	.10	.01
							EPQ Neuroticism	−.08	
94. Keller et al.	2014	951	55.00	15.00	24.63	4.00	NEO-PI-R Conscientiousness	.10	.03
							NEO-PI-R Extraversion	−.07	
							NEO-PI-R Neuroticism	.06	
95. Kelly et al.	2013	66	19.03	1.27	23.41	5.18	UPPS (lack of) Perseverance	−.22	−.03
							UPPS (lack of) Premeditation	.02	
							UPPS Negative Urgency	−.02	
							UPPS Sensation Seeking	.13	
							Conner's CPT Commission Errors	−.11	
							WCST Perseverative Errors	.05	
96. Kelly et al.	2014	186	19.24	1.52	24.38	4.57	UPPS (lack of) Perseverance	.001	.001
							UPPS (lack of) Premeditation	.001	

(*table continues*)

Table 3 (*continued*)

Authors	Year	*N*	Age		BMI		Impulsivity measure(s)	ES (*r*)	Average ES (*r*)
			Mean	*SD*	Mean	*SD*			
							UPPS Negative Urgency	.05	
							UPPS Sensation Seeking	−.05	
97. Koritzky et al.	2012	76	34.64	4.82	29.06	2.68	I7 Impulsivity	.22	.12
							IGT Percent Advantageous Cards	.02	
98. Koritzky et al.	2014	66	44.46	12.60	34.11	7.06	IGT Percent Advantageous Cards	−.30	−.29
99. Lafrance Robinson et al.	2013	165	20.80	5.00	23.20	4.60	DERS Impulse	.07	.07
100. Langenberg et al.	2015	71	41.40	11.90	46.90	6.00	IGT Net Score	−.15	−.15
101. Larsen et al.	2004	168	37.30	8.70	45.90	5.60	DPQ Neuroticism	.12	.12
102. Lattimore et al.	2015	25	24.78	8.67	25.12	5.36	BIS Attentional Impulsivity	.22	.07
							BIS Motor Impulsivity	−.12	
							BIS Nonplanning Impulsivity	.06	
							SST Stop Signal Reaction Time	.12	
103. Leitch et al.	2013	80	22.16	.30	22.90	.89	BIS Attentional Impulsivity	.06	.07
							BIS Motor Impulsivity	.25	
							BIS Nonplanning Impulsivity	.00	
							BART Average Adjusted Number of Pumps	.01	
							DDT Indifference Point	.13	
							GNG Reaction Time	.06	
							MFFT Error	−.04	
104. Lillis et al.	2012	290	41.60	13.60	—	—	Stroop Interference	.27	.19
							GNG Inhibition	.10	
105. Lim et al.	2015	68	23.00	5.90	24.41	5.75	MCQ Indifference Point	.12	.12
106. López-Pantoja et al.	2012	121	36.54	10.36	31.42	4.39	BIS Attentional Impulsivity	.05	.08
							BIS Motor Impulsivity	.05	
							BIS Nonplanning Impulsivity	.17	
							EPQ Extraversion	−.10	
							EPQ Neuroticism	.16	
							TCI Novelty Seeking	.16	
107. Malmir et al.	2014	260	35.11	8.62	27.65	3.50	WCST Perseverative Errors	.34	.34
108. Matsumoto et al.	2015	51	23.82	5.58	20.99	1.71	IGT Net Score	.03	.03
109. Mobbs et al.	2010	88	34.71	10.55	27.99	3.13	UPPS (lack of) Perseverance	.35	.36
							UPPS (lack of) Premeditation	.27	
							UPPS Negative Urgency	.65	
							UPPS Sensation Seeking	.11	
110. Munro et al.	2011	54	41.59	2.40	32.66	2.96	IPIP Conscientiousness	.09	.01
							IPIP Extraversion	−.13	
							IPIP Neuroticism	.08	
111. Murphy et al.	2014	233	19.65	2.15	22.78	4.00	UPPS (lack of) Perseverance	−.02	.04
							UPPS (lack of) Premeditation	.14	
							UPPS Negative Urgency	.04	
							UPPS Positive Urgency	.04	
							UPPS Sensation Seeking	−.01	
112. Mussap et al.	2006	120	25.94	5.43	24.30	—	SPSRQ Sensitivity to Punishment	.10	.01
							SPSRQ Sensitivity to Reward	−.09	
113. Nederkoorn et al.	2006	59	41.33	6.98	31.17	3.83	EPP Impulsivity	.18	.16
							DDT Indifference Point	.13	
							SST Stop Signal Reaction Time	.17	
114. Nederkoorn et al.	2009	57	20.00	1.40	22.00	1.60	SST Stop Signal Reaction Time	.12	.12
115. Nederkoorn et al.	2009	94	20.30	3.10	22.10	2.90	SST Stop Signal Reaction Time	.03	.03
116. Nederkoorn et al.	2010	51	19.50	2.20	21.40	2.20	SST Stop Signal Reaction Time	−.08	−.08
117. Nederkoorn et al.	2014	118	29.89	9.10	24.52	2.82	SST Stop Signal Reaction Time	.05	.05
118. O'Mahony et al.	1995	96	21.10	3.30	21.70	2.60	EPQ Neuroticism	.10	.10
119. Peterson et al.	2010	107	28.87	6.15	26.20	3.85	MPQ Constraint	−.09	−.10
							MPQ Negative Emotionality	−.01	
							MPQ Positive Emotionality	−.19	
120. Pignatti et al.	2006	40	45.03	12.23	32.17	3.92	IGT Net Score	.34	.34
121. Pignatti et al.	2013	20	27.80	7.00	21.60	1.40	TCI Novelty Seeking	−.16	−.02
							WCST Perseverative Errors	−.10	
122. Poston et al.	1999	102	42.89	11.08	38.60	5.60	KSP Impulsiveness	.12	.12
123. Roemmler-Zehrer et al.	2015	114	55.10	10.60	25.60	4.23	EPQ Extraversion	−.25	.09
							EPQ Neuroticism	.41	
124. Rubinstein et al.	2006	60	39.23	8.72	24.79	—	NEO-PI-R Conscientiousness	.47	.13
							NEO-PI-R Extraversion	−.55	

(*table continues*)

Table 3 (*continued*)

Authors	Year	*N*	Age Mean	Age *SD*	BMI Mean	BMI *SD*	Impulsivity measure(s)	ES (*r*)	Average ES (*r*)
							NEO-PI-R Neuroticism	.47	
125. Schag et al.	2013	51	39.65	12.21	29.08	3.54	BIS/BAS Reward Responsiveness	.00	.00
126. Scherr et al.	2010	306	19.90	3.71	23.97	5.99	UPPS (lack of) Perseverance	.07	.05
							UPPS (lack of) Premeditation	.04	
							UPPS Negative Urgency	.12	
							UPPS Sensation Seeking	−.06	
							DDT Indifference Point	.07	
127. Shim et al.	2014	4,042	51.81	13.39	23.35	3.25	NEO-PI-R Conscientiousness	.60	−.30
							NEO-PI-R Extraversion	−.09	
							NEO-PI-R Neuroticism	−.90	
128. Sibley et al.	2006	76	22.50	3.10	23.75	3.52	Stroop Interference	.05	.05
129. Steiger et al.	2003	29	21.80	2.00	23.20	5.60	BIS Attentional Impulsivity	.06	.11
							BIS Motor Impulsivity	.26	
							BIS Nonplanning Impulsivity	−.01	
130. Stenbæk et al.	2014	90	42.97	10.67	33.73	3.37	NEO-PI-R Conscientiousness	.18	.13
							NEO-PI-R Extraversion	−.07	
							NEO-PI-R Neuroticism	.26	
131. Stoeckel et al.	2013	24	33.40	9.80	34.30	3.60	DDT Indifference Point	.09	.09
132. Sutin et al.	2011	1,960	56.98	17.02	26.14	4.89	NEO-PI-R Neuroticism	.001	.03
							NEO-PI-R Conscientiousness	.01	
							NEO-PI-R Extraversion	.09	
133. Sutin et al.	2014	15,669	29.00	1.75	29.14	7.54	IPIP Conscientiousness	.09	.04
							IPIP Extraversion	.00	
							IPIP Neuroticism	.02	
134. Sutin et al.	2015	1,013	22.75	5.70	25.27	6.37	NEO-PI-R Conscientiousness	.09	.03
							NEO-PI-R Extraversion	−.07	
							NEO-PI-R Neuroticism	.06	
135. Svaldi et al.	2014	29	40.10	12.11	32.99	5.96	BIS/BAS Behavioral Inhibition System	−.25	−.08
							BIS/BAS Drive	−.04	
							BIS/BAS Fun-Seeking	.06	
							BIS/BAS Reward Responsiveness	−.10	
136. Swami et al.	2013	339	32.06	13.15	23.64	4.90	NEO-PI-R Conscientiousness	.03	.01
							NEO-PI-R Extraversion	−.03	
							NEO-PI-R Neuroticism	.03	
137. Thomas et al.	2015	39	19.70	.20	21.80	.40	BIS Attentional Impulsivity	.05	.03
							BIS Motor Impulsivity	.04	
							BIS Nonplanning Impulsivity	.04	
							BIS/BAS Behavioral Inhibition System	−.21	
							BIS/BAS Drive	.05	
							BIS/BAS Fun-Seeking	.24	
							BIS/BAS Reward Responsiveness	.01	
							SST Stop Signal Reaction Time	−.02	
138. van Ockenburg et al.	2014	2,717	52.90	11.80	26.50	4.20	EPQ Neuroticism	.002	.002
139. Van Strien et al.	2014	60	20.10	2.32	21.17	2.39	SST Stop Signal Reaction Time	−.13	−.13
140. Villarejo et al.	2014	100	—	—	—	—	TCI Novelty Seeking	−.23	−.23
141. Wang et al.	2010	65	23.10	1.50	24.29	4.54	DDT Indifference Point	.27	.27
142. Watson et al.	2013	48	21.63	2.33	23.38	3.34	BIS Attentional Impulsivity	−.03	−.05
							BIS Motor Impulsivity	−.01	
							BIS/BAS Behavioral Inhibition System	−.05	
							BIS/BAS Drive	−.19	
							BIS/BAS Fun-Seeking	−.10	
							BIS/BAS Reward Responsiveness	−.02	
							Stroop Interference	.07	
143. Weller et al.	2008	95	19.59	2.19	29.73	3.88	BIS Attentional Impulsivity	−.07	−.01
							BIS Motor Impulsivity	−.07	
							BIS Nonplanning Impulsivity	−.06	
							DDT Indifference Point	.17	
144. Wenzel et al.	2014	166	19.00	1.21	23.02	4.16	UPPS Negative Urgency	.12	.12
145. Wignall et al.	2011	40	23.90	3.80	23.40	3.80	Stroop Interference	−.09	−.00005
							SST Stop Signal Reaction Time	.03	

(*table continues*)

Table 3 (*continued*)

Authors	Year	*N*	Age Mean	Age *SD*	BMI Mean	BMI *SD*	Impulsivity measure(s)	ES (*r*)	Average ES (*r*)
							BART Average Adjusted Number of Pumps	.06	
146. Wu et al.	2013	74	34.13	8.83	29.65	3.80	BIS Attentional Impulsivity	−.19	.01
							BIS Motor Impulsivity	−.01	
							BIS Nonplanning Impulsivity	.14	
							BIS/BAS Behavioral Inhibition System	.14	
							BIS/BAS Drive	−.07	
							BIS/BAS Fun-Seeking	−.13	
							BIS/BAS Reward Responsiveness	.002	
							SST Stop Signal Reaction Time	.22	
147. Yeomans et al.	2008	147	21.98	.79	23.05	.47	BIS Attentional Impulsivity	.61	.64
							BIS Motor Impulsivity	.87	
							BIS Nonplanning Impulsivity	.81	
							DII Functional Impulsivity	.70	
							DII Dysfunctional Impulsivity	.51	
							DDT Indifference Point	.00	

Note. Dashes indicate missing values that could not be obtained from the article. BART = Balloon Analogue Risk Task; BFI = Big Five Inventory; BIS = Barratt Impulsiveness Scale; BIS/BAS = Behavioral Inhibition System/Behavioral Activation System; BMI = body mass index; CFCS = Consideration of Future Consequences Scale; CGT = Cambridge Gambling Task; CPT = Continuous Performance Test; DDT = Delay Discounting Task; DERS = Difficulties in Emotion Regulation Scale; DII = Dickman Impulsiveness Inventory; DPQ = Dutch Personality Questionnaire; EPI = Eysenck Personality Inventory; EPP = Eysenck Personality Profiler; EPQ = Eysenck Personality Questionnaire; ES = effect size; GNG = Go/No-Go Task; I7 = Eysenck Impulsiveness Questionnaire; IGT = Iowa Gambling Task; IPIP = International Personality Item Pool; KSP = Karolinska Scales of Personality; MCQ = Monetary Choice Questionnaire; MFFT = Matching Familiar Figures Task; MPI = Maudsley Personality Inventory; MPQ = Multidimensional Personality Questionnaire; NEO-PI-R = NEO Personality Inventory-Revised; SPSRQ = Sensitivity to Punishment and Sensitivity to Reward Questionnaire; SST = Stop Signal Task; Stroop = Stroop Color-Word Test; TCI = Temperament and Character Inventory; UPPS = UPPS Impulsive Behavior Scale; WCST = Wisconsin Card Sort Task; ZTPI = Zimbardo Time Perspective Inventory.

cance testing was utilized. Mixed-effects models assume that variability between studies has both fixed and random components beyond sampling error alone (Lipsey & Wilson, 2001), which provides a conservative estimate that is generalizable to the larger population (Nikolakopoulou, Mavridis, & Salanti, 2014). All estimates were computed using the full maximum likelihood method (Lipsey & Wilson, 2001).

Overall weighted mean effect sizes were computed for each type (questionnaire vs. behavioral task) and domain (conceptualized according to the factor structure discussed by Sharma et al., 2014) of impulsivity measure. We further computed overall weighted mean effect sizes for each individual measure of impulsivity included in the present meta-analysis that had two or more available effect sizes. Moderation analyses were conducted to assess whether the type of impulsivity measure moderated the association between impulsivity and BMI. Due to issues of statistical dependency, we were unable to conduct moderation analyses to determine whether the domain of impulsivity moderated the association between impulsivity and BMI. We then conducted exploratory analyses to determine whether additional demographic and study-specific factors, such as age, gender, or study design, differentially affected the relationship between impulsivity and BMI. Finally, to ensure that results were not influenced by data extraction or coding procedures, we examined whether the relationship between impulsivity and BMI differed as a function of how data were obtained (i.e., directly from the article or from the study authors) and what statistic was used in the conversion of effect sizes (i.e., *t* tests, comparable means with standard deviations, or other convertible statistics).

Because there is a risk that relevant studies with nonsignificant findings remain unpublished, and therefore are not included in the present meta-analysis, we used several approaches to examine data censoring and publication bias. First, because we did not sample from unpublished studies, we assessed for differences in effect sizes between studies that did and did not focus on the relationship between impulsivity and BMI as a primary aim. Second, we used the trim and fill procedure to identify and correct for funnel plot asymmetry resulting from publication bias (Duval & Tweedie, 2000). Third, we conducted formal tests of funnel plot asymmetry using the rank correlation test (Begg & Mazumdar, 1994) and the test of the intercept (Egger, Davey Smith, Schneider, & Minder, 1997). Finally, we applied a three-parameter selection method to correct for publication bias (Iyengar & Greenhouse, 1988). This particular method produces an overall weighted mean effect size adjusted for publication bias and compares this adjusted estimate to the unadjusted estimate. Unlike other selection methods, the three-parameter selection method allows for the publication of studies with results that are not statistically significant and accounts for heterogeneity when estimating adjusted effect sizes and has been shown to perform better than more recently proposed approaches to publication bias (McShane, Bockenholt, & Hansen, 2016).

Results

The Meta-Analysis Reporting Standards (MARS) guidelines were utilized in reporting study findings (APA Publications and Communications Board Working Group on Journal Article Reporting Standards, 2008). All results were analyzed using SPSS Version 23 (SPSS Inc., Chicago, IL) with macros provided by Wilson (2010). Findings are reported in Table 4.

Study Characteristics

In total, 142 articles met inclusion criteria and were comprised of 147 independent samples with 315,818 participants. On average, participants were 32.25 (SD = 12.41) years of age and the majority were women (61%; n = 192,277). Of the independent samples included, 97% (n = 142) reported the BMI of participants. Among these samples, the average BMI was 26.63 (SD = 5.73) kg/m^2, with 51% (n = 72) having an average BMI falling within the normal weight range (i.e., BMI less than or equal to 25), 31% (n = 44) having an average BMI falling within the overweight range (i.e., BMI between 25 and 29.9), and the remaining 18% (n = 26) having an average BMI falling within the obese range (i.e., BMI greater than or equal to 30). Although nearly one quarter of studies did not report how BMI was assessed (22%; n = 33), 46% (n = 67) of studies calculated BMI from objectively measured height and weight whereas 32% (n = 47) relied on self-reported height and weight.

The majority of the included articles reported that data were collected from populations residing in Europe (47%; n = 69) or the United States (31%; n = 45). Study populations tended to be characterized as nontreatment seeking (84%; n = 124). However, 10% (n = 14) and 6% (n = 9) of study populations respectively were comprised of either treatment seeking samples or samples that included both treatment seeking and nontreatment seeking participants. With regard to study design, cross-sectional studies were most commonly reported (63%; n = 92), followed by experimental laboratory studies (18%; n = 27), longitudinal studies (16%; n = 23), and treatment trials (3%; n = 5). In total, 36% (n = 53) of studies reported that at least one of their primary aims was to assess the relationship between impulsivity and BMI.

Effect Sizes

Altogether, 322 effect sizes were extracted from the included articles. Effect sizes most commonly were obtained directly from study authors (54%; n = 173) and were computed using correlation coefficients (72%; n = 231). The majority of effect sizes examined the association between questionnaire measures of impulsivity and BMI (66%; n = 211) while the remaining effect sizes examined the association between behavioral task measures of impulsivity and BMI (34%; n = 111). Of the effect sizes included, 20% (n = 64) were coded as belonging to the N/NE domain, 26% (n = 85) were coded as belonging to the E/PE domain, 20% (n = 63) were coded as belonging to the DvC/C domain, 6% (n = 19) were coded as belonging to the Inattention domain, 8% (n = 26) were coded as belonging to the Inhibition domain, 17% (n = 55) were coded as belonging to the Impulsive Decision-Making domain, and 3% (n = 10) were coded as belonging to the Set-Shifting domain. Effect sizes for the association between impulsivity and BMI ranged from −1.49 to 1.34, with the majority of effect sizes shown to be nonsignificant (73%; n = 236).

Among the 147 independent samples included in the present meta-analysis, 59% (n = 87) reported effect sizes from multiple measures of impulsivity. We were able to obtain the correlation coefficients necessary to correct for covariance between multiple measures of impulsivity in 49% (n = 43) of these samples. For the remaining 51% (n = 44) of samples, the overall variance for each sample was computed by averaging the variances of the effect sizes included within each sample, and covariance between multiple measures of impulsivity was not accounted for (Borenstein, Hedges, Higgins, & Rothstein, 2009). Sensitivity analyses subsequently were conducted to determine whether there were any differences in effects between samples for which covariance between multiple measures of impulsivity was and was not accounted for. Because no meaningful differences emerged for any of the proceeding analyses (ps > 0.07), we retained all 147 independent samples for the final analyses reported herein.

Table 4
Weighted Mean Effect Sizes of the Relationship between Impulsivity and Body Mass Index Across Types and Domains of Impulsivity Measures

Variable	k	r [95% CI]	z	p
Measurement type				
Questionnaire	85	.05 [.03, .07]	5.18	**<.00001**
Task	86	.10 [.08,.13]	7.26	**<.00001**
Measurement domain				
DvC/C	43	.10 [.04, .16]	3.34	**.001**
E/PE	55	.02 [−.002, .05]	1.81	.07
N/NE	62	.06 [−.007, .13]	1.77	.08
Inattention	20	.11 [.05, .17]	3.50	**.0005**
Inhibition	25	.06 [−.007, .12]	1.74	.08
Impulsive Decision-Making	46	.10 [.08, .13]	7.07	**<.00001**
Set-Shifting	10	.17 [.02, .31]	2.22	**.03**

Note. Bolded values indicate that the overall weighted mean effect size was significant. DvC/C = Disinhibition versus Constraint/Conscientiousness; E/PE = Extraversion/Positive Emotionality; N/NE = Neuroticism/Negative Emotionality.

Overall Relationship Between Impulsivity and BMI

The random-effects estimate of the weighted mean effect size for the overall relationship between impulsivity and BMI was r = .07 (95% CI [0.05, 0.08]; k = 147; z = 8.14; p < .00001). This finding was calculated from 147 effect sizes and documents the presence of a small, yet statistically significant, positive correlation between impulsivity and BMI. The assumption of homogeneity was not met, $Q_T(146) = 931.05$; $p < .0001$, indicating significant heterogeneity between effect sizes. Indeed, the I^2 index showed that 84% of the total variation was due to variability between effect sizes rather than sampling error alone. Thus, moderator analyses were appropriate.

Relationship Between Impulsivity and BMI Across Types of Impulsivity Measures

Due to issues of statistical dependency among samples contributing an effect size for both questionnaire and behavioral task measures of impulsivity, the overall weighted mean effect size was computed separately for both measurement types. Results are displayed in Table 4. The random-effects estimate of the weighted mean effect size for the overall relationship between questionnaire measures of impulsivity and BMI was r = .05 (95% CI [0.03, 0.07]; k = 85; z = 5.18; p < .00001). Meanwhile, the random-effects estimate of the weighted mean effect size for the overall relationship between behavioral task measures of impulsivity and BMI was $r = .10$ (95% CI [0.08, 0.13]; $k = 86$; $z = 7.26$; $p < .00001$). Together, these findings document the presence of a small, yet statistically significant, positive correlation between both questionnaire and behavioral task measures of impulsivity and BMI.

To determine whether the relationship between impulsivity and BMI was moderated by the type of impulsivity measure used, further analyses were conducted on the subset of samples that contributed only one effect size per measurement type (85%; $n = 125$). Findings from the mixed-effects model showed a significant difference in the variance between questionnaire and behavioral task measures of impulsivity, $Q_B(1) = 5.42$; $p = .02$, which explained 4% of the overall variance in effect sizes, $Q_T(124) = 136.15$; $p = .22$. The weighted mean effect size for questionnaire and behavioral task measures of impulsivity, respectively, were $r = .05$ (95% CI [0.02, 0.07]; $k = 63$; $z = 3.38$; $p = .0007$) and $r = .10$ (95% CI [0.06, 0.13]; $k = 62$; $z = 5.77$; $p < .0001$), indicating that effect sizes were larger among behavioral task measures of impulsivity when compared to questionnaire measures of impulsivity. Importantly, when comparing the overall weighted mean effect sizes between the subset of samples that were and were not included in this moderation analysis, no differences were found for either questionnaire, $Q_B(1) = 0.83$; $p = .36$, or behavioral task, $Q_B(1) = 0.73$; $p = .40$, measures of impulsivity.

Relationship Between Impulsivity and BMI Across Domains of Impulsivity

Due to issues of statistical dependency among samples contributing an effect size for more than one domain of impulsivity, the overall weighted mean effect size was computed separately for each of the seven impulsivity domains and moderation analyses were unable to be performed. Unlike the previous analysis assessing the moderating effect of measurement type on the relationship between impulsivity and BMI, we were unable to conduct analyses to determine whether the relationship between impulsivity and BMI was moderated by the particular domain of impulsivity assessed because the subset of studies that only contributed one effect size per sample within each domain was limited and ultimately unrepresentative of the full body of research. Results are displayed in Table 4. The DvC/C domain of impulsivity was the only domain among questionnaire measures of impulsivity to produce a significant effect size. Specifically, the random-effects estimate of the weighted mean effect size for the overall relationship between the DvC/C domain of impulsivity and BMI was $r = .10$ (95% CI [0.04, 0.16]; $k = 43$; $z = 3.34$; $p = .001$). Meanwhile, the random-effects estimates of the weighted mean effect sizes for the overall relationship between the N/NE and E/PE domains of impulsivity and BMI respectively were $r = .06$ (95% CI [−0.007, 0.13]; $k = 62$; $z = 1.77$; $p = .08$) and $r = .02$ (95% CI [−0.002, 0.05]; $k = 55$; $z = 1.81$; $p = .07$).

Among the behavioral task measures of impulsivity, the Inattention, Impulsive Decision-Making, and Set-Shifting domains all were shown to have significant effect sizes. Specifically, the random-effects estimates of the weighted mean effect sizes for the overall relationship between the Inattention, Impulsive Decision-Making, and Set-Shifting domains of impulsivity and BMI, respectively, were $r = .11$ (95% CI [0.05, 0.17]; $k = 20$; $z = 3.50$; $p = .0005$), $r = .10$ (95% CI [0.08, 0.13]; $k = 46$; $z = 7.07$; $p < .00001$), and $r = .17$ (95% CI [0.02, 0.32]; $k = 10$; $z = 2.22$; $p = .03$). Meanwhile, the random-effects estimate of the weighted mean effect size for the overall relationship between the Inhibition domain of impulsivity and BMI was $r = .06$ (95% CI [−0.007, 0.12]; $k = 25$; $z = 1.74$; $p = .08$). Forest and funnel plots for each of the seven impulsivity domain analyses are included as supplemental material (see Figures S1 through S7 and Figures S8 through S14, respectively).

We additionally have included the overall weighted mean effect size for each individual questionnaire and behavioral task measure of impulsivity in Tables 5 and 6, respectively. As shown, the strength of effect sizes varied widely across individual questionnaire and behavioral task measures of impulsivity. Within each domain of impulsivity, there did not appear to be meaningful patterns of effect sizes across individual measures. Among questionnaire measures of impulsivity, we expected measures of broad personality traits (e.g., neuroticism, extraversion, and conscientiousness) to uniformly have smaller effect sizes than measures of specific impulsigenic traits (e.g., negative urgency, positive urgency, and [lack of] premeditation). This prediction was based on the nature of the broad personality measures included in the present meta-analysis, which were composite measures of several characteristics that encompassed, but did not solely assess, impulsivity. However, there did not appear to be consistent differences in the strength of effect sizes between questionnaire measures of impulsivity that assessed broad personality traits and those that assessed specific impulsigenic traits (see Table 5).

Relationship Between Impulsivity and BMI Across Demographic and Study-Specific Factors

Findings from the mixed-effects model showed no difference in the variance between study design methods, $Q_B(3) = 3.31$; $p = .35$, the various regions of data collection, $Q_B(7) = 11.13$; $p = .13$, the majority gender of study participants, $Q_B(1) = 0.75$; $p = .39$, the treatment seeking status of study participants, $Q_B(2) = 1.19$; $p = .55$, or the way in which BMI was calculated, $Q_B(2) = 0.40$; $p = .82$. In addition, results from the weighted least squares regression analysis assessing the moderating effect of average participant age on the relationship between impulsivity and BMI showed a positive but nonsignificant association ($\beta = 0.08$; 95% CI [−0.0009, 0.003]; $z = 0.93$; $p = .35$).

Assessment for Publication Bias

Findings showed a significant difference in the variance between the source in which effect sizes were obtained, $Q_B(1) = 5.52$; $p = .02$, such that effect sizes obtained directly from the included articles ($r = .09$; 95% CI [0.07, 0.13]; $k = 68$; $z = 6.27$; $p < .0001$) were larger than were those obtained from the study authors ($r = .05$; 95% CI [0.01, 0.08]; $k = 79$; $z = 2.89$; $p = .004$). Moreover, effect sizes converted directly from correlation coefficients ($r = .06$; 95% CI [0.03, 0.08]; $k = 110$; $z = 4.44$; $p < .0001$) were significantly weaker, $Q_B(1) = 6.65$; $p = .01$, than were those converted from other statistics ($r = .12$; 95% CI [0.08, 0.17]; $k = 37$; $z = 5.39$; $p < .0001$). However, this effect no longer was significant after removing effect sizes obtained from the study authors, which all were calculated using correlation coefficients,

Table 5
Weighted Mean Effect Sizes of the Relationship between Impulsivity and Body Mass Index Across Individual Questionnaire Measures of Impulsivity

Measure	Subscale	*k*	*r* [95% CI]	*z*	*p*
Disinhibition versus Constraint/Conscientiousness					
NEO-PI-R	Conscientiousness	11	.16 [−.05, .37]	1.51	.13
BIS	Nonplanning Impulsivity	14	.13 [−.07, .34]	1.3	.19
BIS	Motor Impulsivity	16	.13 [−.96, .35]	1.12	.26
IPIP*	Conscientiousness	4	.09 [.07, .11]	9.42	**<.0001**
UPPS	(Lack of) Premeditation	5	.09 [−.0002, .17]	1.95	.05
I7	Impulsivity	2	.08 [−.17, .32]	.63	.53
BFI*	Conscientiousness	4	.07 [−.04, .18]	1.24	.22
UPPS	(Lack of) Perseverance	5	.04 [−.09, .18]	.61	.54
DII	Dysfunctional Impulsivity	1	—	—	—
MPQ	Constraint	1	—	—	—
Extraversion/Positive Emotionality					
SPSRQ*	Sensitivity to Reward	5	.12 [−.05, .28]	1.4	.16
SPSRQ*	Sensitivity to Punishment	3	.09 [−.13, .31]	.79	.43
TCI*	Novelty Seeking	9	.09 [−.005, .18]	1.86	.06
BFI*	Extraversion	4	.03 [−.02, .08]	1.22	.22
BIS/BAS	Fun-Seeking	8	.03 [−.03, .08]	1.03	.3
BIS/BAS	Behavioral Inhibition System	9	.01 [−.07, .10]	.32	.75
IPIP*	Extraversion	4	.001 [−.02, .02]	.1	.92
UPPS	Sensation Seeking	5	−.01 [−.08, .05]	−.41	.68
BIS/BAS	Reward Responsiveness	10	−.02 [−.08, .03]	−.89	.38
BIS/BAS	Drive	8	−.03 [−.89, .02]	−1.22	.22
NEO-PI-R	Extraversion	12	−.05 [−.11, .02]	−1.42	.16
EPQ	Extraversion	3	−.07 [−.31, .16]	−.61	.54
DII	Functional Impulsivity	1	—	—	—
EPP*	Impulsivity	1	—	—	—
KSP*	Impulsiveness	1	—	—	—
MPQ	Positive Emotionality	1	—	—	—
UPPS	Positive Urgency	1	—	—	—
Neuroticism/Negative Emotionality					
UPPS	Negative Urgency	7	.20 [.03, .37]	2.34	**.02**
EPQ	Neuroticism	8	.10 [.01, .20]	2.27	**.02**
BIS	Attentional Impulsivity	16	.07 [−.06, .20]	1.06	.29
DERS*	Impulse	6	.06 [.01, .10]	2.47	**.01**
BFI*	Neuroticism	4	.03 [−.01, .07]	1.4	.16
IPIP*	Neuroticism	4	.02 [.003, .04]	2.23	**.03**
NEO-PI-R	Neuroticism	14	−.02 [−.45, .42]	−.08	.93
DPQ*	Neuroticism	1	—	—	—
EPI	Neuroticism	1	—	—	—
MPI*	Neuroticism	1	—	—	—
MPQ	Negative Emotionality	1	—	—	—

Note. Weighted overall mean effect sizes only were computed for measures with two or more available effect sizes. Dashes indicate that the overall weighted mean effect size could not be computed because there was only one available effect size for that measure. Measures are listed in descending order according to the strength of the overall weighted mean effect size. Bolded values indicate that the overall weighted mean effect size was significant. Measures marked with an asterisk were not included in the meta-analytic principal-components analysis by Sharma et al. (2014). Descriptions of these measures and known empirical correlations were used to categorize them into the most appropriate domain. BFI = Big Five Inventory; BIS = Barratt Impulsiveness Scale; BIS/BAS = Behavioral Inhibition System/Behavioral Activation System; DERS = Difficulties in Emotion Regulation Scale; DII = Dickman Impulsiveness Inventory; DPQ = Dutch Personality Questionnaire; EPI = Eysenck Personality Inventory; EPP = Eysenck Personality Profiler; EPQ = Eysenck Personality Questionnaire; I7 = Eysenck Impulsiveness Questionnaire; IPIP = International Personality Item Pool; KSP = Karolinska Scales of Personality; MPI = Maudsley Personality Inventory; MPQ = Multidimensional Personality Questionnaire; NEO-PI-R = NEO Personality Inventory-Revised; SPSRQ = Sensitivity to Punishment and Sensitivity to Reward Questionnaire; TCI = Temperament and Character Inventory; UPPS = UPPS Impulsive Behavior Scale.

$Q_B(1) = 1.87$; $p = .17$. These findings suggest a tendency for published articles to report larger effects and fail to report smaller effects. We further found no differences in effect sizes, $Q_B(1) = 2.06$; $p = .15$, between studies that did ($r = .09$; 95% CI [0.06, 0.13]; $k = 53$; $z = 4.94$; $p < .0001$) and did not ($r = .06$; 95% CI [0.03, 0.09]; $k = 94$; $z = 4.35$; $p < .0001$) focus on the relationship between impulsivity and BMI as a primary aim, thereby mitigating concern for publication bias.

Inspection of the forest plot displayed in Figure 2 revealed a tendency for the included effect sizes to be positively skewed. The funnel plot of observed studies displayed in Figure 3 further revealed that the majority of effect sizes were positive. As expected, larger studies were clustered around the combined effect size at the top of the funnel plot with smaller studies concentrated toward the bottom (Rothstein, Sutton, & Borenstein, 2006). Indeed, results from the rank correlation test ($r_\tau = -0.18$; $p < .001$)

Table 6
Weighted Mean Effect Sizes of the Relationship between Impulsivity and Body Mass Index Across Individual Behavioral Task Measures of Impulsivity

Task	Measure/Subscale	*k*	*r* [95% CI]	*z*	*p*
Inattention					
Stroop	Error	2	.21 [.12, .30]	4.65	**<.00001**
Stroop*	Interference	18	.10 [.03, .17]	2.72	**.007**
Inhibition					
GNG	Inhibition	2	.10 [−.01, .21]	1.7	.09
IGT	Net Score	11	.08 [−.01, .17]	1.71	.09
GNG*	Reaction Time	8	.05 [−.07, .18]	.81	.42
IGT	Percent Advantageous Cards	2	−.14 [−.45, .18]	−.85	.39
CPT*	Commission Errors	1	—	—	—
CGT*	Quality of Decision Making	1	—	—	—
MFFT	Error	1	—	—	—
Impulsive Decision-Making					
MCQ*	Indifference Point	4	.22 [.12, .33]	4.34	**<.00002**
DDT	Indifference Point	19	.14 [.11, .17]	8.61	**<.00001**
CFCS*	Total Score	3	.13 [.06, .20]	3.69	**.0002**
BART	Average Adjusted Number of Pumps	3	.07 [−.10, .24]	.78	.43
ZTPI*	Future	4	.03 [−.04, .09]	.79	.43
SST	Stop Signal Reaction Time	22	.02 [−.03, .07]	.85	.4
Set-Shifting					
WCST	Perseverative Errors	9	.17 [.007, .33]	2.05	**.04**
WCST*	Categories Completed	1	—	—	—

Note. Weighted overall mean effect sizes only were computed for measures with two or more available effect sizes. Dashes indicate that the overall weighted mean effect size could not be computed because there was only one available effect size for that measure. Measures are listed in descending order according to the strength of the overall weighted mean effect size. Bolded values indicate that the overall weighted mean effect size was significant. Measures marked with an asterisk were not included in the meta-analytic principal-components analysis by Sharma et al. (2014). Descriptions of these measures and known empirical correlations were used to categorize them into the most appropriate domain. BART = Balloon Analogue Risk Task; CFCS = Consideration of Future Consequences Scale; CGT = Cambridge Gambling Task; CPT = Continuous Performance Test; DDT = Delay Discounting Task; GNG = Go/No-Go Task; IGT = Iowa Gambling Task; MCQ = Monetary Choice Questionnaire; MFFT = Matching Familiar Figures Task; SST = Stop Signal Task; Stroop = Stroop Color-Word Test; WCST = Wisconsin Card Sort Task; ZTPI = Zimbardo Time Perspective Inventory.

and test of the intercept, $t(145) = 3.77$; $p < .001$, both were significant, suggesting a tendency for large studies to be included in the analysis regardless of their reported effect size and for small studies to be included only when they had a relatively large effect size. However, using the trim and fill analysis, no additional studies were added or trimmed under the random-effects approach, leaving the weighted mean effect size unchanged. Moreover, results from the three-parameter selection method showed no differences, $\chi^2(1) = 0.0008$; $p = .98$, in the overall weighted mean effect size when publication bias was ($r = .07$; 95% CI [0.03, 0.12]) and was not ($r = .07$; 95% CI [0.05, 0.09]) adjusted.

Discussion

The aims of the present meta-analysis were threefold. First, we sought to document the magnitude and directionality of the overall relationship between impulsivity and BMI among adult populations. Second, we assessed the relative contribution of questionnaire and behavioral task measures of impulsivity in relation to BMI. Third, we aimed to determine which specific domains of impulsivity were associated with BMI. As expected, a statistically significant and positive overall effect size was found between impulsivity and BMI, indicating that higher levels of impulsivity were associated with greater BMI. However, the magnitude of this overall effect size was small and there remained substantial heterogeneity of variance. This finding is reflective of the multifaceted nature of BMI as a construct and implicates impulsivity as one of many meaningful contributors to weight status.

Moderation analyses demonstrated that the overall relationship between impulsivity and BMI was influenced by the type of impulsivity measure utilized. Although both questionnaire and behavioral task measures of impulsivity yielded significant and positive effect sizes, the positive effect of impulsivity on BMI was significantly larger among behavioral task measures of impulsivity than among questionnaire measures of impulsivity. This finding is consistent with that of others (Thamotharan et al., 2013) and provides further support for previous evidence documenting limited overlap between questionnaire and behavioral task measures of impulsivity (Cyders & Coskunpinar, 2011; Duckworth & Kern, 2011; Lane, Cherek, Rhoades, et al., 2003; Reynolds et al., 2006). As previously discussed, both questionnaire and behavioral task measures of impulsivity offer researchers several advantages to assessing impulsivity but also are accompanied by unique psychometric challenges. Whereas questionnaire measures assess broad domains of impulsive behavior over time, behavioral task measures objectively assess behaviors reflective of impulsive processes. Because questionnaire measures assess trait levels of impulsivity and require a high degree of insight and honesty in responding, they suffer from issues of subjectivity and may be limited in their ability to reliably predict state occurrences of impulsive action under varied conditions. In contrast, behavioral task measures of impulsivity are particularly adept at modeling specific behav-

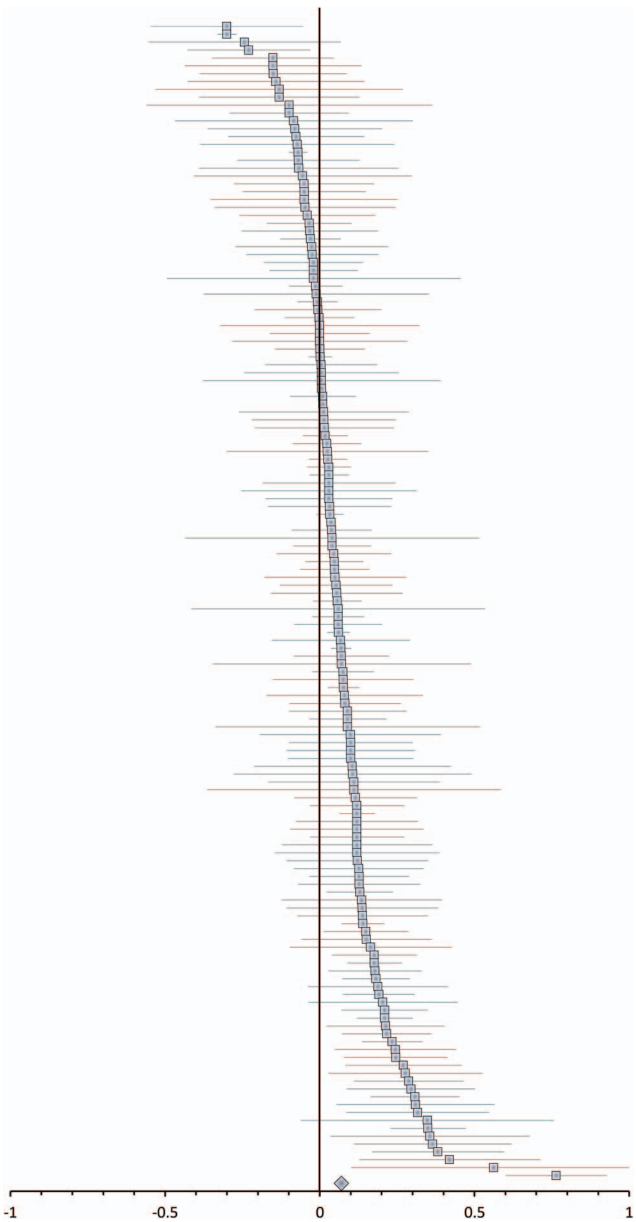

Figure 2. Forest plot of individual study effect sizes for impulsivity and body mass index with 95% confidence intervals. See the online article for the color version of this figure.

ioral processes under controlled circumstances and can provide insight into state fluctuations in behavior but also are sensitive to environmental effects and may not be generalizable to naturalistic settings. Furthermore, the questionnaire measures of impulsivity evaluated in the present meta-analysis included both broad measures of personality traits that contain impulsive features as well as specific measures of impulsigenic traits. Although there did not appear to be consistent differences in the strength of effect sizes between questionnaire measures that assess broad personality traits and those that assess specific impulsigenic traits, it is possible that the overall effect size for questionnaire measures of impulsivity was reduced because many of the measures included were not designed to solely assess impulsivity. Accordingly, questionnaire and behavioral task measures of impulsivity should be carefully selected for the particular research question being tested, and researchers would likely benefit from utilizing multiple types of impulsivity measures to comprehensively assess trait and state constructs of impulsivity.

Additional analyses documented that the overall relationship between impulsivity and BMI further varied across different domains of impulsivity. Impulsivity measures belonging to the DvC/C, Inattention, Impulsive Decision-Making, and Set-Shifting domains all produced positive and significant effect sizes while impulsivity measures belonging to the N/NE, E/PE, and Inhibition domains produced positive but nonsignificant effect sizes. Importantly, due to issues of statistical dependency among samples contributing multiple effect sizes, we were unable to conduct pairwise comparisons to determine whether the strength of these effects varied across domains of impulsivity. However, these findings ultimately support emerging evidence showing that distinct facets of impulsivity differentially promote addictive (Lane, Cherek, Rhoades, et al., 2003) and appetitive behavior (Schag, Schonleber et al., 2013) and further suggest that impulsive characteristics associated with the DvC/C, Inattention, Impulsive Decision-Making, and Set-Shifting domains are most heavily implicated within the context of elevated BMI. Although we are unable to determine the specific mechanisms that may link these particular domains of impulsivity to obesity, a discussion of the accumulating evidence aimed at providing insight into how individuals high on these impulsive characteristics are at risk for obesity is provided in the proceeding sections.

Disinhibition Versus Constraint/Conscientiousness and BMI

With regard to questionnaire measures of impulsivity, we found that only those belonging to the DvC/C domain had a positive and significant effect on BMI, a finding consistent with that of others (Jokela et al., 2014). The DvC/C domain broadly measures a general inability to engage in planned and thoughtful action, persevere on difficult or monotonous tasks, and maintain inhibitory control, which together can promote problematic health behaviors. Individuals high on disinhibition and low on constraint or conscientiousness indeed are likely to display increased sedentary behavior, poor medication adherence, substance abuse, and an unhealthy diet (Bogg & Roberts, 2004). Although several neural mechanisms that contribute to the trait characteristics of the DvC/C domain of impulsivity have been identified, the neural basis of this construct has only recently begun to be understood. Neuroimaging research has found conscientiousness to be positively associated with broad brain regions involved in working memory and goal pursuit (DeYoung et al., 2010), which likely contributes to the difficulty that individuals low on conscientiousness have in constraining impulses to follow rules and sustain behavior that promotes health and longevity. However, these associations have not consistently been demonstrated (Bjornebekk et al., 2013), highlighting a need to further elucidate the neural mechanisms contributing to the expression of trait DvC/C.

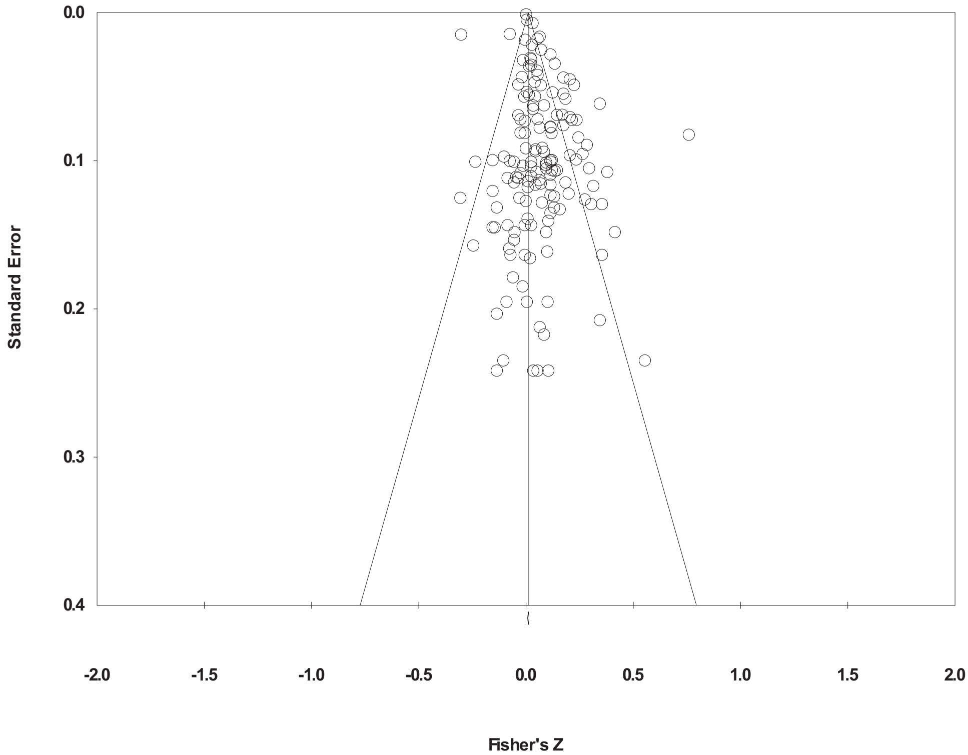

Figure 3. Funnel plot of observed studies to determine publication bias. The trim and fill analysis indicated that no additional studies were to be added or trimmed under the random-effects approach, leaving the weighted mean effect size unchanged.

As a consequence of the reduced self-regulatory capacity characteristic of the DvC/C domain, individuals high on disinhibition and low on constraint or conscientiousness have a tendency toward a heightened responsiveness to situational, habitual, and emotional cues that trigger disinhibited behavior. For example, such individuals are at particular risk of engaging in disinhibited eating (Heaven, Mulligan, Merrilees, Woods, & Fairooz, 2001), which itself contributes to a susceptibility to weight gain over time (Hays & Roberts, 2008), greater difficulties losing excess weight (Butryn, Thomas, & Lowe, 2009), and weight regain following weight loss interventions (Bryant, King, & Blundell, 2008) as well as higher risk for eating pathology (Brown, Bryant, Naslund, King, & Blundell, 2006) and greater binge eating severity (d′Amore et al., 2001; de Zwaan et al., 2003). Accordingly, individuals high on disinhibition and low on constraint or conscientiousness may be at risk for obesity because of their difficulty resisting urges to eat despite satiation, inability to maintain dietary restraint, and tendency to overeat in response to food palatability, negative affect, and social settings. A recent systematic review outlined mounting evidence showing that measures of DvC/C consistently are related to heightened risk for overweight and obesity as well as greater weight gain over time (Gerlach, Herpertz, & Loeber, 2014). Recent meta-analytic findings further have demonstrated a robust association between conscientiousness and the development and persistence of obesity (Jokela et al., 2013), such that individuals low on conscientiousness had nearly 40% higher odds of obesity compared to those high on conscientiousness. Thus, a trait disposition toward high disinhibition and low constraint or conscientiousness may elevate risk for obesity through a vulnerability to engage in external eating.

Inattention and BMI

Similar to previous studies (Allan, Johnston, & Campbell, 2010; Fagundo et al., 2012; Gunstad et al., 2007), we also found a significant and positive effect between behavioral task measures of impulsivity belonging to the Inattention domain and BMI. Attentional deficits are associated with behaviors that confer obesity risk, including greater intake of fatty foods (Allan et al., 2010; Allom & Mullan, 2014; Hall, 2012) and disinhibited eating (Higgs, Dolmans, Humphreys, & Rutters, 2015). A study by Hall, Lowe, and Vincent (2014) demonstrated that adults with higher levels of inattention were more likely to overeat in response to palatable food cues than were those with lower levels of inattention and that this effect was augmented in a permissive food environment. The authors speculated that this pattern of results emerged because individuals with higher levels of inattention may be particularly prone to directing attention toward rewarding food cues and less capable of regulating their eating behavior in facilitative environments (Hall et al., 2014). Indeed, it has been postulated that inattention and related deficits in executive functioning may result in reduced interoceptive awareness of hunger and satiety, making it difficult to adhere to a regular pattern of eating (Davis, Levitan, Smith, Tweed, & Curtis, 2006). However, more recent theories have speculated that attentional dysfunction may lead to a vulnerability toward addiction that subsequently promotes compulsive overeating (Davis, 2010).

Theories of addiction state that repeated exposure to addictive substances activates neural reward systems that foster the development of an attentional bias toward substance-related cues through associative conditioning (Robinson & Berridge, 1993). Palatable foods are similar to other addictive substances in their ability to activate neural reward pathways (Avena, Rada, & Hoebel, 2008) and can further alter brain mechanisms associated with appetitive behavior after continued use (Grigson, 2002; Spring et al., 2008). Like individuals with addiction, individuals with obesity report cravings for (Franken & Muris, 2005) and difficulties resisting urges to consume palatable foods (Bickel et al., 2014). Individuals with obesity further demonstrate an attentional bias toward rewarding food cues (Lawrence et al., 2012), which is thought to be reflective of a motivational drive to approach palatable foods (Volkow & Wise, 2005). However, reviews of the literature have highlighted mixed support for an association between attentional processing of food cues in individuals with overweight and obesity (Nijs & Franken, 2012; Werthmann, Jansen, & Roefs, 2015). Although these inconsistent findings may reflect methodological differences in the way attention is measured (Nijs & Franken, 2012), there is some evidence to suggest that individuals with overweight and obesity display an attentional avoidance of food during attempts at weight loss (Nathan et al., 2012; Werthmann et al., 2011). Thus, individuals with an attentional bias for food, reflective of an underlying pathology toward addiction, may be at particular risk for obesity, though this relationship may depend on dieting status.

In the present meta-analysis, the Inattention domain only included effects from the Stroop task on BMI and did not include effects from other measures of inattention. The Stroop task requires respondents to name the color of a written color word while inhibiting the impulse to read the word itself and is indicative of a general ability to selectively attend to a stimulus. Importantly, we did not include food variants of the Stroop task in the computation of our effect sizes and thus cannot draw conclusions about attentional biases toward food cues in relation to BMI. Instead, our findings suggest the presence of a broader, less specific deficit in attentional processing among individuals with higher BMI relative to those with lower BMI. A study by Enticott, Ogloff, and Bradshaw (2006) comparing associations between questionnaire and behavioral task measures of impulsivity found the Stroop task to be positively correlated with questionnaire measures of nonplanning impulsiveness, attentional impulsiveness, and motor impulsiveness, suggesting that the Stroop task is related to trait deficits in suppressing inappropriate or irrelevant information that can interfere with the achievement of goals, a finding consistent with emerging evidence linking poor Stroop performance to neural regions associated with disinhibited behavior (Maayan, Hoogendoorn, Sweat, & Convit, 2011). Therefore, our finding relating poor attentional control to higher BMI may result from a sensitivity to selectively attend to and approach rewarding substances, such as palatable foods.

Impulsive Decision-Making and BMI

We further documented a positive association between measures belonging to the Impulsive Decision-Making domain of impulsivity and BMI. Impulsive decision-making broadly is defined as a tendency to make risky decisions as well as a general inability to tolerate reinforcement delays and has been implicated as a risk factor for several problematic health outcomes, including substance abuse and dependence (MacKillop et al., 2011), pathological gambling (Brand et al., 2005), and obesity (Lawyer, Boomhower, & Rasmussen, 2015; Weller, Cook, Avsar, & Cox, 2008). Neuroimaging and behavioral studies suggest that impulsive decision-making primarily is driven by an interaction between two neurobehavioral systems, including an appetitive system that pursues immediate gratification and an inhibitory system that seeks to minimize negative outcomes and maximize long-term gains (Appelhans, 2009; Bickel et al., 2007; Bickel & Yi, 2008). Specifically, individuals with a tendency toward impulsive decision-making display heightened neural activation in appetitive systems in conjunction with reduced neural activation in inhibitory systems, which together promote an increased motivation to engage in immediately rewarding behaviors and a greater difficulty delaying gratification in favor of future rewards.

As a consequence of this particular pattern of neural activation, individuals who characteristically engage in impulsive decision-making are more likely to exhibit problems inhibiting behavioral responses to food (Hege et al., 2015) and have a preference for immediate over delayed palatable food intake (Rollins, Dearing, & Epstein, 2010), thereby increasing their likelihood of overeating and placing them at heightened risk for overweight and obesity (Jarmolowicz et al., 2014; Rasmussen, Lawyer, & Reilly, 2010; Schiff et al., 2016). Evidence further has linked both neural and behavioral measures of impulsive decision-making to unhealthy food preferences and poor weight maintenance following weight loss intervention (Weygandt et al., 2015). In line with the present findings, a study by Lawyer, Boomhower, and Rasmussen (2015) found BMI to be significantly related to measures of impulsive decision-making but not to measures of inhibition. Moreover, two recent meta-analyses documented medium effect sizes between risk for obesity and measures of impulsive decision-making associated with both food and monetary rewards (Amlung, Petker, Jackson, Balodis, & MacKillop, 2016; Wu et al., 2016). Taken together, these findings suggest that individuals with a general disposition toward impulsive decision-making may be at specific risk for obesity through increased responding to and overconsumption of palatable foods as well as an intolerance for the delayed reinforcement necessary for weight loss.

Set-Shifting and BMI

The positive association we found between the Set-Shifting domain of impulsivity and BMI is consistent with the results from a recent meta-analysis by Wu et al. (2014) documenting small to medium effect sizes between measures belonging to the Set-Shifting domain of impulsivity and obesity. Poor set-shifting ability is associated with deficits in executive functioning that promote concrete and rigid approaches to problem solving and perseverative behaviors (Roberts, Tchanturia, Stahl, Southgate, & Treasure, 2007) and is heavily linked to the compulsive traits characteristic of eating and weight disorders (Aloi et al., 2015; Fagundo et al., 2012). Neuropsychological evidence indeed has shown that the cognitive inflexibility characteristic of poor set-shifting ability disrupts normative processes involved in habit learning and causes individuals to persistently engage in both positively and negatively reinforcing behavior, despite adverse consequences (Dalley et al., 2011). With regard to obesity, evidence suggests that poor set-shifting ability may lead an individual to compulsively overeat, particularly in response to emotional distress. This behavioral response pattern subsequently promotes an energy surfeit that can lead to excess weight gain if sustained over time and has further been shown to compound risk for disordered eating (Wu et al., 2014).

Although we conceptualized the domains of impulsivity included in the present meta-analysis according to the factor structure described by Sharma et al. (2014), it is important to note that set-shifting frequently is recognized as a measure of compulsivity rather than of impulsivity (Wildes & Marcus, 2013). Impulsivity and compulsivity generally are considered to be two related but distinct constructs that have shared neurobiological underpinnings and lead to difficulties inhibiting dysfunctional thoughts and behaviors. Whereas impulsivity is described as a tendency to act on immediate urges either before or despite consideration of negative consequences (DeYoung, 2010), compulsivity is characterized by the habitual engagement in behaviors that are intended to prevent negative consequences from occurring or to reduce emotional distress (Fineberg et al., 2010). Despite evidence for overlap in the neurobiological mechanisms associated with impulsivity and compulsivity, several important variations have been observed. For instance, impulsive and compulsive behavior are driven by distinct neuropathways that connect different regions in the prefrontal cortex to those in the striatum and are differentially influenced by dopaminergic and serotonergic systems (Fineberg et al., 2014). Accordingly, our finding linking set-shifting to higher BMI may be more reflective of a disposition toward compulsivity than toward impulsivity.

An additional consideration worth highlighting is that the Set-Shifting Domain of impulsivity in the present meta-analysis only included effects from the Wisconsin Card Sorting Task (WCST) on BMI and did not include effects from other measures of set-shifting. The WCST is a complex task that requires subjects to match a target card with one of four category cards under uncertain and unpredictably changing conditions. Although the WCST is purported to measure executive functioning, it has been shown to draw on widespread neural networks associated with varied cognitive processes, bringing into question the validity and specificity of this task as a pure marker of frontal dysfunction (Nyhus & Barcelo, 2009). Moreover, perseverative errors on the WCST frequently are used as an index of cognitive inflexibility but can actually reflect disruptions in two discrete neurocognitive processes, defined as set-shifting and reversal learning (Wildes, Forbes, & Marcus, 2014). Whereas set-shifting denotes an ability to shift attention away from one stimulus toward another, reversal learning reflects an ability to override a previously reinforced behavior in favor of a more adaptive response. Importantly, set-shifting and reversal learning may uniquely contribute to obesogenic behaviors. For example, impaired set-shifting ability may lead individuals with obesity to have difficulty directing attention away from rewarding food cues, thereby increasing their likelihood of engaging in disinhibited eating (Avila et al., 2003). Meanwhile, poor reversal learning may impede the ability of individuals with obesity to modify their habitual use of palatable foods as a reward in order to develop healthier alternatives (Zhang, Manson, Schiller, & Levy, 2014). Given the difficulties interpreting findings from the WCST, future work is needed to disentangle the mechanisms driving the overall association found between the Set-Shifting domain of impulsivity and BMI in the present meta-analysis.

Future Directions and Limitations

These findings provide important foundational knowledge of the specific impulsigenic traits that are most influential in promoting elevated BMI and further underscore the importance of using multiple measures of impulsive characteristics when assessing the relationship between impulsivity and BMI. However, there is a need for additional research to replicate and extend these findings. It will be particularly important for future research on impulsivity and obesity to understand how the impulsigenic traits identified in the present meta-analysis interrelate to increase risk for obesity. Emerging models of convergence and divergence between questionnaire and behavioral task measures of impulsivity have documented unique patterns of overlap across diverse constructs of impulsivity (Cyders & Coskunpinar, 2011; Duckworth & Kern, 2011), and several recent efforts have started to disentangle these interrelations in the context of obesity. For example, Bongers et al. (2014) found that high scores on a trait measure of disinhibition were associated with greater attentional biases toward food cues among obese participants. However, Becker, Fischer, Smith, and Miller (2016) demonstrated that an attentional bias toward food cues was unrelated to the increased palatable food consumption they observed among individuals high on negative urgency following a negative mood induction. These varied findings suggest that trait and behavioral domains of impulsivity may differentially relate to predict obesogenic processes, and future work should aim to assess specific mechanisms, such as those involved in neural reward systems, driving the relationship between these domains of impulsivity and obesity.

Research also is needed to determine how to adjust intervention efforts to best target and address the problematic behavioral patterns common to those high on these particular impulsigenic traits during weight loss treatment. Although intervention efforts aimed at improving self-regulatory capacity can successfully reduce a broad range of maladaptive behaviors (Baumeister, Gailliot, DeWall, & Oaten, 2006), the success of weight loss interventions specifically targeting impulsive eating behaviors has been equivocal (Allom & Mullan, 2015; Veling, van Koningsbruggen, Aarts, & Stroebe, 2014). Moreover, because heightened levels of adiposity can lead to dysfunction in executive processes associated with impulsive characteristics (Fagundo et al., 2012; Waldstein & Katzel, 2006), the relationship between impulsivity and obesity may vary as a function of weight status. Indeed, emerging evidence further has shown that performance on behavioral task measures of impulsivity can improve as a result of weight loss (Dao et al., 2013). Accordingly, understanding the dynamic relationship between trait and behavioral domains of impulsivity and obesity intervention will allow for better tailored individualized treatment plans for weight loss.

It is important that these findings be considered in the context of certain limitations. First, although BMI is a well validated proxy measure of adiposity and is the most commonly used metric to classify overweight and obesity (Welborn & Dhaliwal, 2007), numerous limitations to its use as a health risk indicator have been cited (Prentice & Jebb, 2001). As such, although we are able to conclude that higher levels of impulsivity are associated with a greater amount of weight relative to height, we are unable to conclude whether higher levels of impulsivity directly relate to excess accumulation of body fat. Accordingly, future research assessing the relationship between impulsivity and more direct measures of body composition is warranted. Second, because we were interested in using measures of impulsivity that were consistent with or related to those utilized in the analysis by Sharma et al. (2014), we only included general measures of impulsivity and did not include measures specifically focused on eating- or food-related impulsivity. Given that domain-specific measures of impulsivity have been shown to better predict related impulsive behaviors (Tsukayama, Duckworth, & Kim, 2012), the focus on domain-general measures of impulsivity in the present meta-analysis may have contributed to the small effect sizes we found between impulsivity and BMI. For example, the relationship between the impulsiveness facet of a widely used neuroticism subscale and BMI has been shown to be largely driven by two eating-related items (Vainik, Mõttus, Allik, Esko, & Realo, 2015). Moreover, a recent systematic review documented that neurocognitive and questionnaire measures of impulsivity assessing food motivation tended to provide the most robust and reliable associations with BMI (Vainik et al., 2013). Thus, there remains a need to determine whether eating- and food-related measures of impulsivity produce comparable results with those found in the present meta-analysis. Third, the domains of impulsivity assessed in the present meta-analysis were categorized according to a previous meta-analytic principal-components analysis (Sharma et al., 2014), which represents only one of several empirically supported means of hierarchically structuring measures of impulsivity. As such, it should be acknowledged that our findings may differ as a function of varied theoretical conceptualizations of impulsivity. Moreover, given the ongoing debate regarding the utility of "lumping" versus "splitting" impulsivity constructs (Gullo, Loxton, & Dawe, 2014), we also computed the overall weighted mean effect sizes for each individual measure of impulsivity included in the present meta-analysis. Fourth, the present meta-analysis was not designed to uncover third variable explanations for the relationship between impulsivity and BMI. Although we did not find that the relationship between impulsivity and BMI significantly varied by any demographic or study-specific moderators, future work is needed to determine whether the association between impulsivity and BMI is better explained by such factors. For example, one study found that there was a positive relationship between impulsive decision-making and obesity only among women and not men (Horstmann et al., 2011), suggesting that gender may be an important variable to consider when evaluating the relationship between impulsivity and weight status. Finally, the present meta-analysis did not impose a formal system to assess the quality of the articles included and further excluded unpublished studies, which together may serve as a source of bias. Indeed, the effects between impulsivity and BMI included herein were positively skewed. However, the overall weighted mean effect size remained unchanged when we adjusted for publication bias.

Conclusion

Despite these limitations, the present meta-analysis is the most comprehensive effort designed to understand how questionnaire and behavioral task measures of impulsivity differentially relate to BMI. Although we found that behavioral task measures of impulsivity produced larger effect sizes in relation to BMI, questionnaire measures of impulsivity also yielded significant and positive effects. In particular, impulsive traits associated with disinhibited behaviors, attentional deficits, impulsive decision-making, and cognitive inflexibility were independently associated with higher BMI. Although additional research is needed to further explore the mechanisms driving the relationship between these particular impulsigenic traits and BMI, these findings ultimately help to clarify who may be at risk for overweight and obesity and further provide a preliminary model for how those individuals may be risk.

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*References marked with an asterisk indicate studies included in the meta-analysis.

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Received June 29, 2016
Revision received February 16, 2017
Accepted February 23, 2017 ■