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Curiosity: A conceptual re-analysis for improved measurement

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Abstract
Decades of curiosity research point to its importance as a psychological construct in many significant life domains—including cognitively, emotionally, socially, and physically. However, accurate measurement of the curiosity construct remains an issue. This paper attempts to fill the theoretical void by re-analyzing the seminal research on curiosity. Grounding curiosity in the work of Berlyne, this paper shows how curiosity conceptually morphed over time to include flawed interpretations of Berlyne's work, which are the basis for the current psychometric issues. Since Berlyne's research is foundational to current curiosity research, precisely operationalizing his conception of curiosity is required to resolve the measurement problems.

Keywords Curiosity · Collative variables · Curiosity measurement

Introduction

Adapting the definition from Berlyne (1950, 1954, 1960, 1966, 1978), curiosity is a motivational drive or need for knowledge that is aroused by collative variables and expressed through different types of exploratory behavior to gain information. Decades of curiosity research point to its importance as a psychological construct cognitively, emotionally, socially, and physically across the lifespan. As such, all of the significant life domains are impacted by curiosity, since the resource of knowledge derived from curiosity is critical to human growth and survival (Berlyne, 1960; Grossnickle, 2016; Harrison, 2012; Kashdan & Steger, 2007; Kashdan et al., 2018; Kashdan, Stiksma et al., 2018; Loewenstein, 1994; Reio et al., 2006; Voss & Keller, 1983).

The curiosity construct has been studied from many perspectives with a few topics dominating the research for decades: whether curiosity is a state or a trait, whether its origins are intrinsic or extrinsic, and whether curiosity is uni-dimensional or multi-dimensional. Research also has centered on specific areas such as institutions (e.g., education, vocational, and religious) and general life (e.g., personal and social) (Grossnickle, 2016; Harrison et al., 2011; Kashdan, Stiksma et al., 2018; Loewenstein, 1994; Reio et al., 2006; Voss & Keller, 1983).

Researchers have called for studies that establish the relationship of curiosity to "hardened outcomes" in important life domains (Kashdan & Silvia, 2009, p. 372). However, numerous psychometric issues have arisen in measuring curiosity, which must be resolved for the field of curiosity research to advance. This paper will show that the crux of the measurement issues is from a flawed interpretation of the seminal curiosity research.

Framing the seminal curiosity research

At its most basic, curiosity is a motivational drive, a need for knowledge or information that is aroused by collative variables and the outcomes of that motivational drive are expressed either behaviorally and/or emotionally through different types of exploratory behavior (Berlyne, 1950, 1954, 1960, 1966, 1978; Loewenstein, 1994).

Motivational approach as a foundation

Contemporary empirical research on curiosity can be traced to the work of Berlyne (1950, 1954, 1960, 1966, 1978) who sought to understand "the laws of curiosity" (Berlyne, 1950, p. 69) initially through behaviorist and learning psychology

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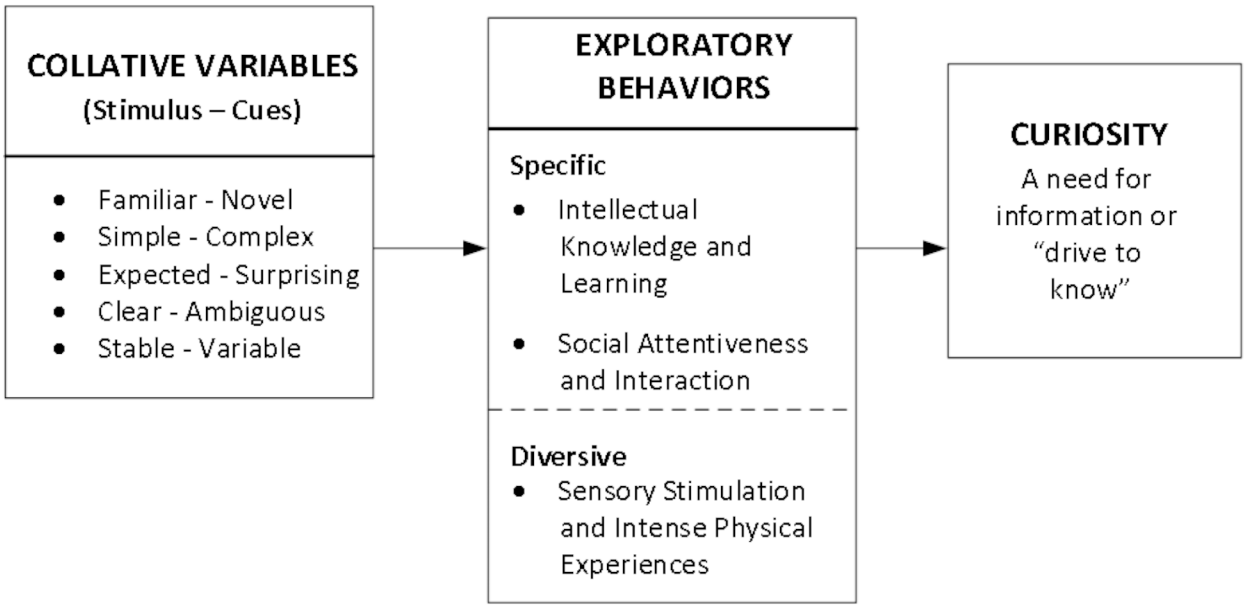

Fig. 1 The Relationship Between the Constructs of Curiosity. Curiosity as a need for information is aroused by the stimulus-cues called collative variables, which can evoke two types of exploratory behaviors—specific and diversive. Only the two specific exploratory behaviors are considered curiosity. The diversive type of exploratory behavior is not considered curiosity. Created from "A Theory of Human Curiosity," *British Journal of Psychology: General Section*, by D. E. Berlyne, 1954, *45*(3), p. 187, and *Conflict, Arousal, and Curiosity* by D. E. Berlyne, 1960, McGraw-Hill Book Company.

principles. Defining curiosity as a "drive to know," (Berlyne, 1954, p. 187), his decades of work in information theory identified the conditions that evoked curiosity motivationally (Berlyne, 1966).

Connecting the concept of curiosity to exploratory behavior in rats, Berlyne was the first to distinguish between curiosity aroused by innate drives, which he termed *instrumental exploration* (Berlyne, 1950, p. 71) and curiosity aroused by the novelty of external stimuli. In his subsequent work, Berlyne (1954) delineated curiosity found in animals and humans, which varied in the types of stimuli that evoked the curiosity drive. *Perceptual* curiosity, found in both animals and humans, is evoked by new, ambiguous sensory stimuli, which leads to sensory exploratory behavior (e.g., visual, auditory, or olfactory inspection); the drive in perceptual curiosity is to experience and feel. *Epistemic* curiosity, found only in humans, is evoked by complex ideas or unknowns, which leads to cognitive exploratory behavior that increases knowledge; the drive in epistemic curiosity is to know (Berlyne, 1954, pp. 180, 187). The basis of both perceptual curiosity and epistemic curiosity is that the experience or knowledge gained reduces the conflict, or incompatibility, aroused by the stimulus or stimuli (Berlyne, 1954, 1960).

Both perceptual curiosity and epistemic curiosity are aroused by factors called *collative variables* as shown in the box displayed in the first column of Fig. 1. Drawing in the animal or human, these collative variables require analysis or comparison (Berlyne, 1960, p. 44; 1966, p. 153), which introduces quantifiable stimulus characteristics that vary in their properties along several dimensions: "familiar-novel, simple-complex, expected-surprising, ambiguous-clear, and stable-variable" (Berlyne, 1974, p. 5). These collative variables are subjective in their experience by individuals (Berlyne, 1974).

There are three types of perceptual responses or behaviors to stimuli that can occur: *orienting* (i.e., altering the position of a "sense organ" such as nose, eyes, or ears), *locomotor* (i.e., movement), or *investigatory* (Berlyne, 1960, p. 79). The first two responses occur within the individual, and the third involves interaction with the external environment.

There are three types of epistemic responses to stimuli that can occur: *consultation* (e.g., answering or asking questions), *observation*, and *thinking* (Berlyne, 1960, p. 265). The range of epistemic responses shows that there not only is an immediate information-seeking mode that reduces situational uncertainty but also futuristic modes of behavior such as knowledge acquisition and thinking, which occur due to conflicts in *thoughts, beliefs, attitudes, conceptions* (Berlyne, 1966, p. 31), leading to exploratory behavior in an effort to resolve the conflict. These exploratory behaviors can occur "for their own sake"—meaning that there does not have to be an immediate purpose or gain in the search for knowledge exploration and indeed, may be pursued while forsaking biological drives such as hunger or safety (Berlyne, 1966, p. 25).

Using a combined neurobiological and psychological analysis, two conditions with differing motivational bases are posited that explain exploratory behavior for both perceptual curiosity and epistemic curiosity (Berlyne, 1960, pp. 79–80; 1960, pp. 26–27).

1. *Diversive* exploratory behavior: This state occurs in an under-stimulated state (e.g., boredom, wanting entertainment, or seeking a new experience) where additional stimulation or arousal from a variety of sources is sought out to end the perceived conflict.
2. *Specific* exploratory behavior: This state occurs in an over-stimulated state when faced with inadequate information and a specific stimulus is sought out to end the perceived conflict as quickly as possible.

The resolution of conflict created by these two polarized states—diversive and specific—motivates the different types of exploratory behavior. The intensity of the stimuli evokes a hedonic tone. Specifically, stimuli in a moderate range that are the most rewarding evoke pleasant responses; this optimal range is called *arousal potential* (Berlyne, 1960, p. 200). Stimuli that are below (i.e., causing understimulation) and above (i.e., causing over-stimulation) the arousal potential range result in unpleasant experiences. Graphed out, the stimulus intensity and the hedonic tone form a Wundt curve, which is an inverted U (Berlyne, 1960).

Most crucial is that Berlyne (1960, 1966) labeled only specific exploratory behavior—behavior that seeks out information from a specific stimulus—as curiosity. Further, Berlyne (1966, 1978) viewed specific exploratory behavior of curiosity and diversive exploratory behavior as being separate constructs, rather than a single construct on a continuum with specific exploratory behavior at one end and diversive exploratory behavior at the other end. Specific exploratory behavior, or curiosity, occurs only within the optimal arousal potential range. As noted above, Berlyne (1966) theorized that curiosity, specific exploratory behavior, is initiated by high arousal or an over-stimulated state, which can range from high to low with the collative variables identified by Berlyne (1974, p. 5) as *novel, complex, surprising, ambiguous*, and *variable* evoking high arousal because the contrast or variance is strong and those that are *familiar, simple, expected, clear*, and *stable* evoking low arousal because the contrast or variance is weak. Thus, the opposite of a state of being highly curious is not boredom but instead, the state of arousal is at the low to neutral end of the stimuli perception range.

While both types of exploratory behavior—specific and diversive—deal with resolution of conflict, the use of the term *conflict* does not mean that the perception or situation is wholly negative or aversive. Instead, the use of the term *conflict* means that there is some recognition of a degree of contrast or some variance that can range in intensity from high to low that introduces varying levels of uncertainty (Berlyne, 1954). For specific curiosity, a stimulus can be simultaneously challenging and exciting, resulting in an overall positive state. In contrast, diversive exploratory behavior induced by boredom is more likely to result in an aversive or negative state (Day & Berlyne, 1971). Yet, positive affect still can occur in a state of boredom, such as an anticipatory response of when that state will end (Berlyne, 1960).

Theoretical support for Berlyne's work. Significant theoretical support for the motivational state that drives exploratory behavior for information as conceptualized by Berlyne is supported in the research literature and has been extended through other theories. With the exception of work on the Perceptual Curiosity Scale, which explores individual differences in sensory exploratory behavior (Collins et al., 2004), the majority of curiosity research is around epistemic curiosity.

In a major review of the literature, Loewenstein (1994) summarized the curiosity research regarding its definition, dimensions, causes, and situational (i.e., state) determinants. Then, in merging ideas from Gestalt and social psychology as well as decision theory, he proposed a complex theory, called Information Gap Theory (IGT), that sought to integrate the fragmented and partial views of curiosity research that had occurred over the prior century and especially since the end of Berlyne's work that spanned three decades into the 1970s. Labeling his theory as "an integrative interpretation of epistemic curiosity," IGT intersects both cognition and motivation research by focusing on curiosity as a state, which occurs when there is recognition of a "gap in ... knowledge" that arises as a result of either internal or external factors and leads to a search for the missing information to resolve the resulting tension (Loewenstein, 1994, pp. 86–87). Therefore, the missing information in any situational context is the stimulus that drives curiosity, which increases as the information gap narrows and diminishes when sufficient information is acquired.

IGT proposes four features of curiosity, which are consistent with drive theory: (a) *Intensity*: There is a *loss* perspective in that curiosity is driven by an aversive state of deprivation, which is minimized or ended when the information is obtained; (b) *Transience*: The drive ends when the information is gained; (c) *Impulsive*: The drive to seek out information is immediate to reduce the *cognitively induced* state of deprivation; (d) *Disappointment upon satiation*: The obtainment of information that satisfies curiosity places the person in a *neutral hedonic state*, because of the temporal aspect of taking in information is immediate, rather than gradual (Loewenstein, 1994, p. 92). Later research on IGT

theory by Loewenstein and colleagues studied the theory's neural underpinnings of epistemic curiosity (Kang et al., 2009).

Synthesis. The seminal theory of curiosity developed and expanded by Berlyne (1950, 1954, 1960, 1966, 1978) remained focused on the acquisition of knowledge or information through exploratory behaviors aroused by the collative variables. Only the construct of specific exploratory behavior is called curiosity, which occurs within the optimal arousal potential range of the collative variables. Later research by Loewenstein (1994) integrated crucial tenets of Berlyne's work. Continuing to cite Berlyne's extensive research as a foundation, subsequent research in curiosity investigated how exploratory behaviors are expressed.

Outcomes of the curiosity motivational drive: behavioral and emotional expressions of exploratory behavior

Both Berlyne (e.g., 1960, 1966) and Loewenstein (1994) viewed curiosity as a broad motivational state, which is transient and elicited by a given situation. However, by the mid-1960s, curiosity as trait, which is a stable predisposition or an individual difference, also became a focus of the research (Boyle, 1983). The state and trait distinctions are related in that individuals who are high in the trait of curiosity experience state curiosity with greater frequency and intensity (Boyle, 1989; Harrison, 2012; Harrison et al., 2011; Kashdan & Silvia, 2009; Spielberger & Starr, 1994).

Berlyne (1960) acknowledged that individual differences in personality factors, culture, and biology affect an individual's response to a given stimulus and thus, their arousal potential range. However, in his work, Berlyne chose not to address individual differences fully (Boyle, 1983). Curiosity as an individual trait is expressed differently in terms of the types and intensity of behavior and emotions it evokes (Kashdan et al., 2004; Kashdan & Silvia, 2009; Langevin, 1971; Litman, 2005; Litman & Jimerson, 2004; Litman & Silvia, 2006; Litman & Spielberger, 2003; Voss & Keller, 1983). These behavioral and emotional expressions often coexist, meaning that behavior is bound up in emotions and vice versa as noted by Wohlwill (1987, p. 64) in stating that stimulus exploration has "both an information-extraction and affect-production function."

In reviewing the curiosity literature, the individual differences in the behavioral and emotional expression of exploratory behaviors, both *specific* and *diversive*, fall into three broad categories: intellectual knowledge and learning, social attentiveness and interaction, sensory stimulation and intense physical experiences. The theories presented in each of the three categories differ in the type of information an individual is driven to seek out (Litman & Pezzo, 2007). These exploratory behaviors are shown in the box displayed in the second column of Fig. 1. Summary information on the curiosity scales and inventories are listed in chronological order in Table 1.

Intellectual knowledge and learning. The most researched area is around the acquisition of information and knowledge. Several theories describe the specific exploratory behavior of epistemic curiosity as evoking an individual to pursue information in an effort to gain knowledge or learn, which can result in positive emotions of interest and pleasure or negative emotions such as anxiety, fear, and confusion.

Exploratory behavior is a hallmark of intrinsic motivation where engaging in a behavior or activity is rewarding in and of itself (Deci, 1975). Berlyne's work is credited by Deci (1976) as forming the basis for the physiological needs of intrinsic motivation. The psychological needs of intrinsic motivation are based on *competence* and *self-determination*, which produce two broad classes of behavior to achieve those needs: *seeking* and *conquering* (Deci, 1976, pp. 130–131).

Deci's research on intrinsic motivation became the foundation of Self-determination Theory (SDT; Deci & Ryan, 2000; Ryan & Deci, 2000). The crux of SDT is that *autonomy, relatedness*, and *competence* are psychological needs, creating an *integrated self* (Deci, 1992, p. 44; Ryan & Deci, 2000, p. 231), which is essential to fulfillment in multiple life domains (e.g., education, athletics, work) as well as overall well-being (i.e., psychological health and life satisfaction). When present, these three needs support the "natural activity and curiosity referred to as intrinsic motivation" (Ryan & Deci, 2000, p. 76), resulting in positive outcomes. Alternately, when the three needs are stymied, intrinsic motivation is reduced, leading to negative outcomes that can lead to alienation and withdrawal (Ryan & Deci, 2000). Intrinsic motivation also specifically relates to curiosity, a dispositional trait, in that engaging in activities of interest is intrinsically rewarding. SDT addresses the interaction between the person and the activity in a given context or situation, and those activities that are characterized by *optimal challenge* and *novelty* spark interest or curiosity the most (Deci, 1992, p. 50), a stance that is consistent with Berlyne's (1960, 1966) conception of collative variables as evoking curiosity.

Based on Spielberger's extensive work on the emotion of anxiety (e.g., Spielberger, 1966; Spielberger, Gorsuch, & Lushene, 1970), Spielberger and Starr (1994) summarized a complex theory, called Optimal Stimulation/Dual Process Theory of Exploratory Behavior, that extends Berlyne's work on optimal arousal. Their theory posits that the two different types of exploratory behavior—specific and diversive—can be explained by the curiosity drive and

Table 1 Summary Information of Curiosity Measures in Chronological Order

Scale/Inventory Name and Date	Dimension(s) of Curiosity Measured	Consistent with Berlyne's Theory
Sensation Seeking Scale (Multiple Forms) (1964, 1968, 1971)	Intensity and variety of sensation seeking behaviors	No
Epistemic Curiosity Scale (2003)	Individual differences in cognitive exploratory behavior with Specific and Diversive subscales	No
Curiosity as a Feeling of Deprivation (CFD) (2004)	Reducing negative feelings associated with perceived uncertainty	No
Perceptual Curiosity Scale (2004)	Individual differences in sensory exploratory behavior with Specific and Diversive subscales	No
Curiosity and Exploration Inventory (CEI) (2004)	Exploration (sensation seeking and cognitive) and Absorption (engagement level)	No
Sensory Curiosity Scale (2005)	Novel and unusual sensory experiences as a dimension of curiosity that is distinguished from intense sensation seeking behaviors	Partially
Social Curiosity Scale (2006)	Level of interest (General subscale) and tactics (Covert subscale) deployed in acquiring information about others	No
Interpersonal Curiosity Scale (2007)	Type and method used in obtaining information about others	No
Curiosity and Exploration Inventory-II (CEI-II) (2009)	Adaptation of the CEI (2004) with Embracing and Stretching subscales	No
Five-Dimensional Curiosity Scale (5DC) (2018)	Subscales of Joyous Exploration, Deprivation Sensitivity, Thrill Seeking, Stress Tolerance, Social	No
Five-Dimensional Curiosity Scale Revised (5DCR) (2020)	Revisions to the same five subscales as the 5DC by eliminating weak items and expansion of the Social subscale	No

anxiety drive working in tandem, rather that the singular arousal potential (i.e., optimal range) of the curiosity drive. Diversive exploratory behavior is activated by low levels of collative variables where anxiety is non-existent or low. Specific exploratory behavior is activated when collative variables reach a moderate level and associated anxiety levels are low to moderate. Thus, curiosity occurs as a state of optimal arousal evoked by increasing collative variables (e.g., novel stimuli or experiences) that activates the brain's reward center, which is an approach orientation. However, too much arousal increases anxiety, which triggers an aversive reaction in the brain, resulting in avoidance behavior. Individuals who are high in trait curiosity and trait anxiety will experience both the states of curiosity and anxiety with greater intensity (Spielberger & Starr, 1994).

The Information Gap Theory posed by Loewenstein (1994) recognized curiosity to seek out information as both aversive and pleasurable. As an aversive condition, curiosity arises as a feeling of deprivation that must be relieved or eliminated, motivating a person to seek out information. However, voluntary exposure to curiosity can create pleasure if a person thinks that the pursuit of the information will be satisfied in a short time frame and that obtaining the information will outweigh the aversive aspect of the curiosity state.

In the development of the Epistemic Curiosity Scale (EC Scale), Litman and Spielberger (2003) claim that curiosity is a single but multi-dimensional construct with the cognitive aspects of epistemic curiosity and the emotional aspects of perceptual curiosity as two distinctive but correlated dimensions. The authors identified separate exploratory behaviors—specific (S) and diversive (D)—creating subscales labeled specific epistemic curiosity (EC/S) and diversive epistemic curiosity (EC/D) for the EC Scale.

Exploring epistemic curiosity as both a feeling of interest (CFI) and feeling of deprivation (CFD), Litman and Jimerson (2004) developed a theory, called the I/D Theory of Curiosity, to determine the structural properties of each, which they concluded to be psychometrically distinct. Several scales attempt to measure curiosity as a feeling of interest, a positive feeling that occurs when there is an opportunity to seek out information or something captivates attention, whereby an individual is motivated to induce or maintain the pleasurable, rewarding state. These scales include the curiosity subscale of the Values in Action Inventory (Peterson & Seligman, 2004), the Epistemic Curiosity Scale (Litman & Spielberger, 2003), and the Perceptual Curiosity Scale (Collins et al., 2004). With the I/D Theory, the authors attempt to fill a psychometric gap by developing a scale that measures curiosity as a feeling of deprivation, a

negative feeling that occurs when there is perceived uncertainty, and an individual is motivated to reduce or eliminate the aversive state. Curiosity as a feeling of deprivation has stronger motivational force than curiosity as a feeling of interest, which in citing Loewenstein (1994), is consistent with decision theory that losses are perceived as more significant than equivalent gains. This I/D model was further studied in additional research (Litman, 2008; Litman & Silvia, 2006).

Coping as an adaptive behavior to counter potentially aversive conditions caused by curiosity has been a topic in the curiosity research. Berlyne (1960) referenced the importance of the ability to cope with the anxiety evoked by ambiguous and novel stimuli in epistemic exploratory behavior. Similarly, Boyle (1983, p. 384) presented *coping styles* as a factor that followed the cognitive appraisal of the collative variables. Silvia (2008a, 2008b) used the Appraisal Theory of Emotion, which allows for individual differences in emotional responses to stimuli to be analyzed, in exploring the specific collative variables of novelty and clarity. In his studies, he found that novelty and clarity created curiosity whereas novelty and ambiguity do not but instead, create a negative experience due to a lack of coping abilities. As initially posited by Berlyne (1960) and Boyle (1983), the ability to cope or have *stress tolerance* (Kashdan, Stiksma et al., 2018, p. 132) remains an important factor in the curiosity research, as its presence allows curiosity to induce positive affect.

Social attentiveness and interaction. One of the newer lines of research studies the specific exploratory behavior of epistemic curiosity as evoking social attentiveness towards and interactions with other people.

The concept of *social curiosity*—defined as wanting to know "how other people behave, think, and feel"—is key to building and maintaining relationships as well as learning (Renner, 2006, p. 305). Social curiosity is based on early research by Singer and Antrobus (1963) who introduced the concept of interpersonal curiosity, which is the desire to know information about the lives of others. Their research on various factors related to daydreaming revealed that a general tendency to daydream appeared similar to interpersonal curiosity. Renner's work extended beyond that of Singer and Antrobus (1963) in that the daydreaming was passive and did not necessarily motivate exploratory behavior to seek out social information.

Renner (2006, p. 309) created a scale, called the Social Curiosity Scale (SCS), that measures two factors in acquiring information about others: intensity of interest labeled *General Social Curiosity* (SCS-G) and the types of tactics deployed labeled *Covert Social Curiosity* (SGS-C). The study showed social curiosity to be a distinct facet of curiosity that is different from the cognitive and sensory facets and is trait-like in that there are individual differences in its expression. Additionally, the study revealed new findings that ran counter to prior theoretical concepts related to social anxiety, specifically that social anxiety did not diminish social curiosity but instead, socially anxious people employed more covert tactics to gain information (e.g., eavesdropping).

Recognizing that the research on interpersonal curiosity focused primarily on the external lives of other people, research by Litman and Pezzo (2007, pp. 1448–1449) developed a revised Interpersonal Curiosity Scale that measures the *type* of information (internal such as thoughts and feelings as well as external such as where a person attends school or works) and *method* used to obtain it (overt and covert) resulting in three subscales that represent the sources of information: *Curiosity about Emotions*, *Spying and Prying*, and *Snooping*. Counter to prior research, the authors found that interpersonal curiosity was unrelated to high social needs or extraversion, since their scale also measured the desire for information, which does not necessarily require the interaction with others to obtain it. The research supported Renner's (2006) finding that socially anxious people use covert tactics to gain information.

Sensory stimulation and intense physical experiences. Several theories describe the diversive exploratory behaviors that evoke the pursuit of sensory stimulation and/or intense physical experiences, many based on the work of Zuckerman and colleagues who proposed that sensation seeking was a personality trait and spent decades exploring its biosocial origins. Specifically, individuals seek out an optimal level of sensation across a range of behaviors in novel situations with perceived risk. Small to moderate deviations from a given optimal arousal level are perceived as pleasurable but too much deviation becomes unpleasant. Their initial research attempted the development and construct validation of the Sensation Seeking Scale (SSS; Zuckerman et al., 1964; Zuckerman & Link, 1968). A revision of the scale added and modified items that measured individual differences in *sensory, social*, and *thrill-seeking* behaviors. Four specific dimensions were identified that represent the intensity and variety of sensation-seeking behaviors: *Thrill and Adventure Seeking, Experience Seeking, Disinhibition, Boredom Susceptibility* (Zuckerman, 1971, p. 45). Later research also explored sensation seeking as a state. The SSS inventory has multiple forms after undergoing several revisions of its items over the years (Zuckerman, 1994).

In other research related to the measurement of sensory stimulation based on Zuckerman's work, Byman (2005) sought to clarify the constructs of curiosity and sensation seeking with results showing psychometric distinction between the cognitive aspects of curiosity and the physical aspects of sensation and thrill seeking, leading the author

to question whether the sensation seeking construct was a dimension of curiosity at all. Cognitive curiosity and sensory curiosity also were distinguished psychometrically by Reio et al. (2006) with the sensory dimension being composed of physical thrill seeking and social thrill seeking. Litman et al. (2005, p. 1125) developed the Sensory Curiosity Scale to measure "novel and unusual sensory experiences," which is consistent with Berlyne's (1966) definition of perceptual curiosity and different from Zuckerman's (1971) extreme conception of sensation seeking in that the Sensory Curiosity Scale did not focus on risky behaviors.

Synthesis. More than a half century of curiosity research has investigated the behavioral and emotional expressions of exploratory behaviors. The common root of all of these different exploratory behaviors is seeking out some type of information. The three broad areas of research discussed—intellectual knowledge and learning, social attentiveness and interaction, sensory stimulation and intense physical experiences—differ in the type of information an individual is driven to seek out. It is important to note that intellectual knowledge and learning as well as social attentiveness and interaction are manifestations of exploratory behaviors that are congruent with specific curiosity in that a specific stimulus is sought out to relieve the state of having inadequate information. However, the exploratory behaviors of sensory stimulation and intense physical experiences are forms of diversive exploratory behaviors since stimulation or arousal is sought out from a variety of sources to end a perceived deficiency. According to Berlyne's (1960, 1966) theoretical work, these types of diversive exploratory behavior are not considered a form of curiosity and no empirical work has supported diversive exploratory behavior as consistent with the curiosity construct.

Discussion

Psychometric issues with curiosity measurement

The philosopher, Edmund Burke, characterized curiosity as "the first and simplest emotion" (1756/2014, Part I). Over 200 years later, curiosity continues to have a seemingly "simple label," but like many psychological constructs is very complex, and this is especially so with curiosity having "physiological, behavioral, and phenomenological" factors (Langevin, 1971, pp. 371–372).

Part of the complexity of the construct is revealed through measurement difficulties that have pervaded the research over the years, ranging from the definition of the construct to the validity of the measures (Boyle, 1983; Byman, 2005, 2016; Grossnickel, 2016; Langevin, 1971; Loewenstein, 1994; Rowden, 2000; Voss & Keller, 1983). For curiosity research to advance, the issues around definition, dimensionality, and measurement must be resolved.

Clarifying the operational definition

The variation in the definition of terms in research studies has posed major measurement problems with the crux of the issue around the concept of exploratory behaviors (Boyle, 1983; Byman, 2005; Langevin, 1971; Voss & Keller, 1983). What is key is that Berlyne identifies two types of exploratory behavior—diversive and specific—in his work. Wohlwill (1981) analyzes a few of the operationalization issues with the diversive and specific exploratory behaviors, noting that Berlyne's conceptualization developed through his research over time. However, as stated earlier, Berlyne only labeled specific exploratory behavior as curiosity, a concept that never changed throughout his research.

According to Langevin (1971), the confusion in the terminology can be traced back to the doctoral dissertation by Day in 1965 where he uses the term *diversive curiosity*, extending Berlyne's conception of diversive exploratory behavior. However, Day's research did not empirically support the concept of diversive exploratory behavior as being that of curiosity. Boyle (1983) recounts Day's unsuccessful attempt to establish the reliability of the Ontario Test of Intrinsic Motivation (OTIM), which he constructed to measure three types of curiosity: specific curiosity, diversive curiosity, and social desirability.

Yet, the incorrect terminology has persisted. Specifically, researchers have used the terms *diversive curiosity* and *specific curiosity* routinely in the literature for decades. As shown in Table 1, only one of the eleven scales and inventories listed is consistent with Berlyne's theory and terminology, though all of the authors cite Berlyne's work as foundational to their research.

By way of example, this diversive—specific definitional issue continues with a recently published curiosity inventory called the Five-Dimensional Curiosity Scale (5DC; Kashdan, Stiksma et al., 2018). In describing the new 5DC inventory, Kashdan, Disabato et al. (2018) wrote:

> To that end we use either what Berlyne called "diversive curiosity" (as when a bored person searches for something—*anything*—to boost arousal) or what he called "specific curiosity" (as when a hyperstimulated person tries to understand what's happening in order to reduce arousal to a more manageable level.) (p. 59)

Additionally, an update to the scale called the Five-Dimensional Curiosity Scale Revised (5DCR) has the same terminology flaw despite the authors claiming that the revision has "greater bandwidth and predictive power" (Kashdan et

al., 2020, p.1). Importantly and as stated earlier, Berlyne never used the term *curiosity* in relation to the concept of *diversive exploratory behavior* (Berlyne, 1978).

Clarifying the dimensions

A related aspect of the definitional issue is around the dimensionality of curiosity. Research over the last 15 years presents curiosity as a multi-dimensional construct (Byman, 2016; Grossnickle, 2016; Kashdan, Disabato et al., 2018; Kashdan, Stiksma et al., 2018; Langevin, 1971; Litman & Spielberger, 2003). But as Byman (2016) points out, there is a lack of agreement as to the number or precise categories of the dimensions, which goes back to an issue of construct validation.

For example, serious theoretical questions remain as to whether thrill seeking types of behaviors like the dimension of sensation seeking appropriately fits the curiosity construct (Byman, 2005). The definition of sensation seeking by Zuckerman (1994, p. 27) is "a trait defined by the seeking of varied, novel, complex, and intense sensations and experiences, and the willingness to take physical, social, legal, and financial risks for the sake of such experiences." He goes on to use the example of a drunk driver as an exemplar of this trait—that doing so is a physical risk because of a possible accident, a legal risk if arrested or jailed, a social risk if friends or business associates find out, and a financial risk if employment is lost (Zuckerman, 1994). The key word in the definition is *willingness*, which denotes a volitional rational decision—when in reality, drunk driving is an impaired, non-rational decision. In measuring sensation seeking, the Sensation Seeking Scale—Form V (Zuckerman, 1994, pp. 389–390) asks questions related to other extreme behaviors around gorging the senses such as illegal drug use, sexual behavior (e.g., "swinging"), and intense sports (e.g., expedition mountain climbing). While Zuckerman (1994) acknowledges that a high need for sensation seeking is associated with psychopathological tendencies such as impulsivity as have previous personality theorists (e.g., Eysenck), these types of sensation seeking behaviors do not resemble curiosity as defined by Berlyne as noted earlier. As it is conceived by Zuckerman and colleagues (see Zuckerman, 1971; Zuckerman, 1994; Zuckerman et al. 1964; Zuckerman & Link, 1968), sensation seeking relates to the concept of diversive exploratory behavior, rather than Berlyne's (1960) definition of specific exploratory behavior from either perceptual curiosity (through orienting, locomotion, or investigatory responses) or epistemic curiosity (through consultation, observation, or thinking responses). In his research, Zuckerman does use some of Berlyne's collative variables terminology, and he also notes the influence in his work regarding Berlyne's conception of optimal arousal level. However, there are many personality traits, both positive and negative, that can be explained in terms of an optimal arousal level (e.g., persistence, anxiety), so the specific link of sensation seeking to curiosity is not theoretically sound.

Thus, there are three critical decisions about any dimension that is under consideration to be included in a curiosity inventory:

1. whether the dimension should be included at all, and
2. if so, determining the appropriate range of the dimension from negative (i.e., pathological) to neutral to positive (i.e., optimal), as well as
3. the weighting of a given dimension in relation to other dimensions.

Though mentioned decades ago as a problem by Langevin (1971) in his discussion of various curiosity measures, the operationalization of the diversive—specific concepts has not been resolved and remains a significant debate in the curiosity research.

Examples of measurement issues with curiosity scales

The ongoing difficulty in measuring curiosity was recently confirmed when two popular inventories were retracted. Using strong language, Kashdan (2018) withdrew, due to validation issues, the Curiosity and Exploration Inventory (CEI; Kashdan et al., 2004) and one of the two subscales, the Embracing subscale, of the Curiosity and Exploration Inventory-II (CEI-II; Kashdan et al., 2009). Both of these inventories were presented as valid and used for years in many research studies. The CEI was touted as "distinguish[ing] itself from other curiosity inventories that tend to lack theoretical frameworks, use idiosyncratic items that evoke nonrandom error, have uncertain incremental validity. . ." (Kashdan et al., 2004, p. 303), and the CEI-II, which was necessitated by validity issues around the breadth of the curiosity construct in the CEI, was presented as having "been subjected to close psychometric scrutiny" over and above that of other inventories (Kashdan et al., 2009, p. 995).

As noted earlier, the 5DC is the most recently released curiosity inventory, which the authors claim provides a multi-dimensional measure of curiosity that will help "to better understand human motivation, behavior, and well-being" in a population that has high heterogeneity. The five subscales of the 5DC are: *Joyous Exploration* based on the work of Deci, *Deprivation Sensitivity* and *Thrill Seeking* based on the work of Zuckerman, *Stress Tolerance* based on the work of Silvia, and *Social Curiosity* based on the work

of Renner as well as Litman and Pezzo (Kashdan, Stiksma et al., 2018, p. 132). This scale was quickly revised and is now called the 5DCR. The number of subscales is the same, but the number of inventory items was rearranged with one item being eliminated from four dimensions and the Social Curiosity subscale lengthened by breaking out the dimension to overt and covert subfactors (Kashdan et al., 2020).

There are two major issues with the 5DC and 5DCR scales around dimensionality and methodology which are the same issues that most of the inventories in Table 1 also possess:

Dimensionality. First, the concern of Byman (2016) remains as to whether these five particular dimensions are *the* correct dimensions that capture the construct of curiosity. A related concern is whether the dimensions should be equally weighed. In past research on curiosity, coping or *stress tolerance* is a variable that supports curiosity (Berlyne, 1960; Boyle, 1983). Indeed, in describing the 5DC, the authors stated that the newly created inventory (Kashdan, Stiksma et al., 2018):

> …was developed to document the fact that human beings have different ways of experiencing and expressing curiosity. These differences are relevant to how people represent things in their minds, and why they are motivated to seek out new information and experiences, discover, learn, and grow. (p. 144)

It is unclear how the dimension of *stress tolerance* fits into "new information and experiences, discover, learn, and grow." As such, it is debatable whether coping or stress tolerance is an independent dimension of curiosity but instead, is a factor that should be weighted less than a dimension like *joyous exploration* which does align with the curiosity research as an independent factor.

Also related to the dimensionality issue is the operationalization of the dimensions. For example, the definition of the word, social, includes these words: *cooperative or interdependent actions with others, pleasant companionship, relating to, interaction* (Social, 2019). Yet all of the items on the 5DC and the majority of items on the 5DCR that ostensibly tap the *social curiosity* dimension represent tactics to elicit information about others rather than actually engaging with others on a personal basis, which is what the word *social* means. Additionally, Schmitt and Lahroodi (2008, p. 139) characterize "nosy ... prying, peeping, voyeurism" as *petty* and not in keeping with epistemic curiosity.

Methodology. The authors' claim that their research ostensibly "organizes the rich theories and methodologies of prior researchers into a single framework" (Kashdan, Stiksma et al., 2018, p. 131). The problem is that many of the theories and methodologies used to construct the 5DC and the 5DCR scales have had their own psychometric issues that another exploratory factor analysis or correlational study does not resolve. A case in point is the Social Curiosity dimension, which is based on the work of Renner (2006). Going back to that original study, Renner (2006) bases the development of the Social Curiosity Scale in part on the development and validation of the CEI by Kashdan et al. (2004), a scale which has been entirely withdrawn (Kashdan, 2018). There are three layers of scales underpinning the Social Curiosity dimension of the 5DCR, which ultimately is based on a retracted scale, and this leads to a shaky psychometric foundation lacking in validity. All of the dimensions of the 5DCR have similar psychometric lineage problems.

Another methodology issue is with the type of instruments developed. Decades ago, Voss and Keller (1983, p. 73) raised the issue of whether "the entire field of curiosity can be comprised in a questionnaire." The authors further pointed out the problem of curiosity researchers developing certain methods (e.g., self-report questionnaires, projective techniques) for use in a study, *generously* interpreting and generalizing their work, and extending an invitation for other researchers to undertake experimental validation studies, but a *dearth* of such follow-up research that produces psychometric clarity or higher validity rarely happens (Voss & Keller, 1983, p. 59). This cycle continues as evidenced by the information in Table 1 with 11 curiosity inventories being introduced in only 16 years from 2004 to 2020 with very few follow-up validation studies across diverse subjects and populations. Further, there have been no experimental studies.

Other methodology concerns with curiosity inventories were raised by Boyle (1983, p. 389), including "narrow scales with high item homogeneity," the inclusion of "transparent self-report items," and issues with factor analytic techniques. The cycle outlined by Voss and Keller (1983) and the issues raised by Boyle (1983) continue with the curiosity research. More recently, Grossnickle (2016) observed that many inventories lack consistency over time that is expected of measures of personality traits and that experimental studies are lacking.

Synthesis

Two specific validation issues with curiosity inventories were detailed by Langevin (1971, p. 372):

1. construct validity, and
2. "the author's intuitive or theoretical conceptions which are built into the scales are never checked against real behavior."

Decades later, Langevin's (1971) concerns were echoed by Byman's (2005) in his comments regarding the number of curiosity inventories:

> This is a confusing situation. It is, for instance, difficult to compare results of studies that have used different curiosity measures. This has led several researchers ... to try to clarify the similarities and differences between existing curiosity scales. That is, they have tried to find out whether different measures of curiosity measure different kinds of curiosity. The answer to this question has been clearly no, but otherwise the findings of these studies have not been unanimous. (p. 1366)

Grossnickle (2016) also called for additional research to improve discriminant validity by ensuring that instruments were actually measuring curiosity and not related constructs. Byman (2005) pondered that the measurement difficulties of curiosity may be due to its structure not being completely understood and that it may be part of a higher order personality dimension, which is a view supported by Mussel (2013).

Summary

The pursuit of understanding curiosity and its fundamental importance to life cannot be understated, and one way of framing its impact is to imagine life without curiosity: "There would be no exploration of the self and the world, introspection, search for meaning in life, aesthetic appreciation, scientific pursuits, innovation, and to some degree, personal growth" (Kashdan & Silvia, 2009, p. 373).

Indeed, research on the importance of curiosity has moved beyond the social sciences research to the more applied sectors of education and business. The education sector has long considered curiosity essential to cognitive development and academic achievement dating back to Dewey's research in the early 1900s (Grossnickle, 2016). Along with persistence and basic intelligence, curiosity is considered one of the three "pillars" of academic success (von Stumm, Hell, & Chamorro-Premuzic, 2011, p. 574). Curiosity as a topic of interest to the business sector is expected to rise given global economic forces, technology, and accelerated rates of change (Harrison et al., 2011; Mussel, 2013). Mussel et al. (2012) developed the first measurement of curiosity designed for organizational settings, the Work-Related Curiosity Scale. More recently, Kashdan et al. (2020) began development on a multi-dimensional curiosity scale for the workplace. Validated instruments in these specific contexts are important, as concerns about the applicability of using general curiosity inventories has been raised (Rowden, 2000). Yet, applied research rests on sound theoretical research, which makes sorting out the psychometric issues with curiosity essential.

Clearly the curiosity construct's definition needs additional study, so that it can be operationalized and measured accurately. Foremost, the current methodology of using other poorly validated curiosity instruments to create and ostensibly validate a new instrument must stop. A completely fresh look by researchers should recalibrate this important area of study, which will require a deeper reading and understanding of Berlyne's terminology. Since the majority of measures of curiosity cite Berlyne's work as foundational, the critical starting point is to precisely operationalize Berlyne's (1960, 1966, 1978) conception of curiosity as pertaining only to specific exploratory behaviors. Only then can the deeper research on the mechanisms that link "curiosity to hardened outcomes" (Kashdan & Silvia, 2009, p. 372) across all of the significant life domains—personal, social, educational, and vocational—be undertaken.

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