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An Assessment of the Relationship between Self-Control and Ambient Temperature: A Reasonable Conclusion is that Both Heat and Cold Reduce Self-Control

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Abstract
The current paper is a review of published literature on the relationship between ambient, environmental temperature and self-control, defined as consisting of discrete domains, namely complex cognition, attention control, aggressive and criminal restraint, passivity, physical persistence, sexual control, work regulation, alcohol and tobacco regulation, helping, and bias avoidance. The typical pattern was that both heat and cold reduced self-control. Optimal self-control was at middle temperatures. An analysis of mediators that account for the relationship indicated that changes in negative affect, arousal, and physiology (energy provision) mediated the effect of temperature on self-control. Temperature is ubiquitous. It may influence people across the world, at all times, meaningfully across important domains of thought and behavior.

Keywords: Temperature, self-control, self-regulation, heat, cold.

Introduction

Temperature is ubiquitous and may have important psychological effect. The following review is an assessment of the hypothesis that temperature - either heat (e.g., above 28° Celsius or 83° Fahrenheit) or cold (e.g., below 15° Celsius or 59° Fahrenheit, or much colder) reduces self-control.

Self-control is domain general. Its assessment therefore consists of the assessment of discrete domains. An overall pattern in these domains is therefore indicative of self-control performance. These domains are complex cognition, attention control, aggressive and criminal restraint, passivity, physical persistence, sexual control, work regulation, alcohol and tobacco regulation, helping, and bias avoidance. Complex cognition includes higher intellect, working memory, decision making, and dual task performance. There is high overlap between self-control and complex cognition, such that they seem to rely on an interchangeable, depletable energy (Gailliot, 2008; Schmeichel, 2007; Schmeichel, Vohs, & Baumeister, 2003; Vohs et al., 2008). Controlling attention requires the self-control of lower order attentional processes via executive functioning. Attention control requires an active, effortful self.

Aggressive urges sometimes arise, and it requires self-control to avoid their expression in thought or behavior. Criminal impulses are tempting to the self, often in the short-term, and require self-control to avoid thinking about and allowing influence on behavior. Self-control requires an active, volitional self, one that requires energy for action (Baumeister, Bratslavsky, Muraven, & Tice, 1998). When people lack self-control, such as after having used self-control, they become more passive (Gailliot, 2013). Thus, there is high overlap between passivity and low self-control. It often requires self-control to motivate oneself to action, override desires to be lazy, and engage onself in active demanding work. Physical persistence requires the self-controlled exertion of will to continue on a physical task and avoid giving up. People often fail at physical tasks because they lack self-control resources, rather than the actual energy to perform a task. The regulation of sexual thought and behavior requires self-control. Sexual thoughts and proclivities to engage in sexual acts emerge on occasion when they require suppression or avoidance, and this requires self-control. Work regulation requires self-control, such as decisions to put forth effort and overriding inclinations to procrastinate or become distracted. If people are less able to use self-control, then they should be less able to control their work related thought and behaviors. People often use self-control to avoid consuming, or to reduce consumption of, tobacco and alcohol. People with good self-control drink and smoke less. People's automatic tendencies drive toward selfishness, and so it requires self-control to override such tendencies instead to help others during situations when altruism is possible. People must also willfully expend the energy to help, which often involves significant time, effort, and risk. The psyche demonstrates automatic biases, or prejudice, that require self-control to stifle in the expression of thought and behavior. Discussing controversial racial issues, for example, requires self-control resources that can be consumed during the interaction.

A major purpose of this review is to provide a test of theoretical explanations for the influence of temperature on self-control. To the extent that heat and cold reduce self-control, then these phenomena are explainable in theoretical terms. It is important to determine which theory best accounts for temperature effects. It should be noted, however, that any effect of temperature on psychological processes likely has many mediators. Temperature may influence one's choice of environment, clothing, and social interactions. Though temperature is complex, the research literature on temperature provides a few major theories that dominate the field and that may account for the relationship between self-control and temperature. The current review paper was based on an assessment of each major theory and the extent to which each provides the best explanation for the observed phenomena.

One explanation is that heat and cold make people feel unpleasant and uncomfortable. This emotional affective experience produces negative affect that reduces self-control. People may have lapses at self-control because they seek to feel better or attention is distracted. The negative affect escape model is that, though temperature may induce negative affect, at hotter or colder temperatures people seek to escape the situation, which may induce good self-control. Though heat may dispose one toward the lowered self-control of aggression, for example, at very hot temperatures people may remain indoors and avoid any potential aggressive situation. Arousal is another mechanism that may account for the influence of temperature on self-control. Both heat and cold increase arousal. Self-control is impaired with increased arousal, as nondominant responses are impaired, and therefore temperature should impair self-control. Another theory is that arousal is misattributed to self-control related phenomeona, thereby prompting self-control failure. In the summer heat, the beer drinker may, for example, attribute increases in arousal from the temperature to desires and excitement over drinking. A different account is that heat and cold increase impulses of self-control failure, thereby making it look like self-control is impaired and reducing self-control. For example, cold may increase sexual desires not because it reduces self-control but because it increases sexual motivation and appeal. Physiological accounts may also explain the link between temperature and self-control. There are undoubtedly a large number of different potential mediators. This review focused on one major category in biology, namely energy metabolism. The theory is that heat and cold deplete energy resources that otherwise would benefit self-control. Routine activity theory is that a given thought or behavior occurs with motivation to engage in such thought or behavior, a suitable situation or outlet, and a lack of that which would prevent the given thought or behavior. Heat and cold therefore might cause self-control reductions via changes in motivation, suitability, and lack of prevention. Cognitive neoassocation, associative and semantic connections between temperature and self-control, might explain the relationship. Heat, for example, activates thoughts of aggression which then prompt aggressive behavior. Cultural norms may account for the relationship to the extent that the given self-control behavior is consistent with pervaiding modes of thought and behavior. Last, economic need theory predicts that heat and cold increase needs that lead to changes in self-control.

The review process indicated that the best mediators between self-control and temperature are changes in negative affect, arousal, and physiology (energy provision). The other major theories, presented abovie, either only partially or poorly explained mediation.

Psychoscientific Assessment of the Hypothesis that Heat and Cold Reduce Self-Control Complex Cognition – Both Heat and Cold Reduce Complex Cognition

It is well established that extreme heat and cold lead to confusion (Chand & Murthy, 2008; Fuller, Carter, & Mitchell, 1998; Mahoney, Castellani, Kramer, Young, & Lieberman 2007; Romero, Clement, & Belden, 2000; Schlader, Stannard, & Mundel, 2010; Walters, Ryan, Tate, & Mason, 2000) and amnesia (Flint & Riccio, 1996; Keating, 1959). Less extreme temperature change also influences cognition.

Heat and Complex Cognition

Many studies indicate that heat reduces performance on cognitive tasks (Allen & Fisher, 1978; Bandelow et al., 2010; Dawson, 1993; Enander & Hygge 1990; Gaoua, 2010; Hancock & Vasmatzidis 2003; Haslam & Parsons, 1987; Hoffman 2001; Keller et al. 2005; Kerslake, 1972; Kobrick, Johnson, McMenemy, 1990a, 1990b, 1990c; Mäkinen, Gavhed et al. 2001; Mäkinen, Palinkas et al. 2006; O'Brien, Mahoney et al. 2007; Ramsey, 1995; Ramsey & Kwon 1992; Rodahl, 2003; Simmons, Saxby, McGlone, & Jones, 2008; Stewart, 2011; Toner, Drolet, & Pandolf, 1986; Viteles & Smith, 1946; Wetsel, 2011; Wright, Hull, & Czeisler, 2002; for a review, see Bell, 1981; for a meta-analysis, see Pilcher, Nadler, & Busch, 2002; cf. Bunnell and Horvath, 1988). More specifically, heat has been found to impair reasoning (Pilcher Nadler Busch 2002), dual task performance (Bell, 1978; Carlson, 1961; Provins & Bell, 1970; Ramsey, 1995; Vasmatzidis, Schlegel & Hancock, 2002), learning and memory (Allen & Fischer, 1978; Cian, Barraud, Melin, & Raphel, 2001; Holland, Sayers, Keatinge, Davis, & Peswani, 1985; Kobrick and Johnson 1992; Sharma, Sridharan, Pichan, & Panwar, 1986; Stewart 2011; Wyon, Andersen, & Lundquist, 1979), decision making (Kobrick and Johnson, 1992; Razmjou & Kjellberg, 1992), working memory (Bandelow 2010; Cian et al., 2001; Hocking, Silberstain, Lau, Stough, & Roberts, 2001; Vasmatzidis, Schlegel, & Hancock, 2002), and executive functioning (Nybo & Nielsen, 2001).

Teacher and principal assessments show that elementary schoolchildren perform worse on intellectual classwork on hot days (Dexter, 1904). College students in another study were tested on learned material in an environmental chamber at ambient temperatures of 17°C, 20°C, 23°C, 27°C, 30°C, or 33°C. They made more errors at hotter temperatures (Pepler & Warner, 1968). Participants in another study performed worse on memory tests while in a hot (50°C) chamber than a thermoneutral (20°C) chamber (Racinais, Gaoua, & Grantham, 2008). Performance on reaction time tasks has been found to be impaired in a hot (37°C) versus thermoneutral (22°C) environment (Bell, Loomis, & Cervone, 1982). Nine year old children performed worse when tested in a hot (30°C or 27°C), compared to a thermoneutral (20°C), room. Dual task performance has been found to be worse in a hot (35°C), compared to a thermoneutral (18°C), environment (Bursill, 1958). Among people in the army, exposure to heat while wearing a flight uniform reduced flight performance in a simulator (Reardon et al. 1997). Students learn and test better in thermocomfortable classrooms (22.5°C-24°C) than in hot classrooms (26°C-29°C; Pepler, 1971; Schoer & Shaffran, 1973).

Cooling the skin has been found to attenuate the harmful effects of heat on cognition (Allan & Gibson, 1979; Allnut & Allan, 1973; Benor & Shvartz, 1971; Nunneley & Maldonado, 1983; Nunneley, Reader, & Maldonaldo, 1982). Heat caused impairments in working memory among participants in one study that were eliminated by the application of cold packs to the skin (Gaoua, Racinais, Grantham, & Massioui, 2011).

A large body of evidence indicates that heat impairs complex more than simple cognition (Carlson, 1961; Cian et al. 2001; Curley & Hawkins, 1983; Enander & Hygge, 1990; Epstein, Keren, Moisseiev, Gasko, & Yachin, 1980; Fine & Kobrick, 1978, 1987; Hancock, 1982, 1986; Hancock & Vasmatzidis 2003; Makinen et al., 2006; McMorris et al. 2006; Mortagy, 1971; Nunneley et al., 1982; Palinkas, Paakkonen, Rintamaki, Leppaluoto, & Hassi, 2005; Patterson, Warlters, & Taylor, 1994; Pilcher et al. 2002; Ramsey, 1995; Wargocki & Wyon 2007; Wetsel, 2011). These findings dovetail with those on self-control, which show that reductions in self-control influence complex, more than simple, cognition (Schmeichel et al., 2003).

Reductions in self-control are more likely when one is less skilled at the task at hand, and a few studies demonstrate that heat reduces complex cognition primarily under such circumstances (Goleman, 1995; Hancock, 1986; Hancock & Vasmatzidis, 2003; Mackworth, 1950; Pepler, 1958). Though heat impaired performance on a language test, the effect was especially pronounced among children who demonstrated relatively less academic skill (Wyon, Andersen, & Lundqvist, 1979). High motivation can overcome the effects of reduced self-control (Muraven & Slessareva, 2003) and, likewise, the effect of heat on complex cognition is less apparent among highly motivated participants (Lana, Liana, Pana, & Yeb, 2009; Hancock, 2003; Bell & Provins, 1962; Pepler, 1963). In one study, participants who received verbal encouragement overcame the harmful effects of heat (Pepler, 1958).

Cold and Complex Cognition

Extreme cold has strong effects on cognition, producing confusion (Mahoney, Castellani, Kramer, Young, & Lieberman 2007) and amnesia (Flint & Riccio, 1996; Keatinge, 1959). Many studies demonstrate that less extreme cold hampers performance on cognitive tasks (Coleshaw, Van Someren, Wolff, Davis, & Keatinge, 1983; Enander, 1987; Enander & Hygge, 1990; Giesbrecht, Arnett, Vela, & Bristow, 1993; Lockhart, Jamieson, Steinman, & Giesbrecht, 2005; Mahoney et al. 2007; Mäkinen, Gavhed et al. 2001; Mäkinen & Palinkas, 2006; O'Brien, Mahoney, Tharion, Sils, & Castellani, 2007; Shurtleff, Thomas, Ahlers, & Schrot, 1993; Teichner & Kobrick, 1955; Thomas, Ahlers, House, & Schrot, 1989; Toner, Drolet, & Pandolf, 1986; Wright, Hull, & Czeisler, 2002; for a meta-analysis, see Pilcher et al., 2002; cf. Kahl 2005; Marrao, Tikuisis, Keefe, Gil, & Giesbrecht, 2005; Slaven & Windle, 1999). College students were found to learn best at a middle temperatures (22.22°C) than at colder (e.g., 11.11°C) or warmer (33.33°C) temperatures (Allen & Fischer, 1978; Pepler & Warner, 1968). In both humans and nonhuman animals, cold has been found to impair many forms of cognitive performance, including learning (Castellani et al., 2003; Department of the Army, 2005; Klenerová et al., 2003; Klenerova et al. 2002), decision making (Banderet & Lieberman, 1989; Ellis, 1982, 1985; Ellis, Wilcock, & Zaman, 1985; Enander, 1987; Teichner, 1958), working memory (Ahlers, Thomas, & Berkey, 1991; Bowen, 1968; Doubt, Weinberg, Hesslink, & Ahlers, 1989; Mahoney et al., 2007; Shurtleff, Thomas, & Ahlers, 1992; Shurtleff, Thomas, Ahlers, & Schrot, 1993; Thomas, Ahlers, House, & Schrot, 1989; Thomas, Ahlers, & Schrot, 1991), reasoning (Castellani et al., 2003; Department of the Army, 2005; Giesbrecht, Arnett, Vela, & Bristow, 1993; O'Brien, Mahoney, Tharion, Sils, & Castellani, 2007; Mahoney et al., 2007), dual task performance (Bell, 1978; Enander, 1984), memory (Andjus, Knopfelmacher, Russell, & Smith, 1956; Allen & Fischer, 1978; Baddeley, Cuccaro, Egstrom, Weltman, & Willis, 1975; Beitel & Porter, 1968; Bowen, 1968; Coleshaw, Van Someren, Wolff, Davis, & Keatinge, 1983; Davis, Baddeley, & Hancock, 1975; Egstrom, Weltman, Baddeley, Cuccaro, & Willis, 1972; Giesbrecht, Arnett, Vela, & Bristow, 1993; Jacobs & Sorenson, 1969; Klenerová et al. 2002; Klenerová, 2003; Lockhart, Jamieson, Steinman, & Giesbrecht, 2005; Nagy, Anderson, & Mazzaferri, 1976; Mahoney et al., 2007; Panakhova, Buresova, & Bures, 1984; Pozos, 1986; Rauch, Welch, & Gallego, 1989; Riccio, Hodges, & Randall, 1968; Richardson, Guanowsky, Ahlers, & Riccio, 1984; Schrot, Thomas, & Shurtleff, 1996; Stillman, Shukitt-Hale, Levy, & Lieberman, 1998; Thomas et al., 1989, 1991; Vanderwolf, 1991; Vaughan, 1977), response inhibition (Klenerová, 2003), reversal learning (Danet, Lapiz-Bluhm, & Morilak, 2010; Lapiz-Bluhm et al., 2009), problem solving (Bowen, 1968; Davis et al., 1975; Vaughan, 1977), and executive functioning (Gunstad et al., 2009). People have reported being less able to think clearly in the cold (Banderet & Lieberman, 1989).

Participants in one study performed worse on the Stroop task and working memory measures while in a cold chamber (Hartley & McCabe, 2001). Navy scuba divers performed worse on navigation problem-solving tasks while in 4.5°C water (Vaughan, 1977). Ninety-minutes of –12°C air worsened choice reaction time (Ellis, 1982). Scuba divers performed worse at choice reaction time in 10°C water than in 16°C water. Cold air exposure has been found to impair memory (Armstrong & Thomas, 1990). Exposure to 10°C air worsened working memory, choice reaction time, and executive functioning (Muller et al., 2012). Living in Antarctica or polar settings has been found to produce cognitive decline, reduced working memory, and dulled thought (Palinkas & Suedfeld, 2007; Reed et al. 2001; Shea, Slack, Keeton, Palinkas, & Leveton, 2011). Seasonal affective disorder, occurring in the winter, is associated with reductions in complex cognition, memory and working memory, learning, and executive functioning (Allen & Fischer, 1978; Michalon, Eskes, & Mate-Kole, 1997; Merikanto et al., 2011; O'Brien, Sahakian, & Checkley, 1993; Rajajärvia et al., 2010).

Consistent with evidence showing stronger links between self-control and complex, rather than simple, cognition, much work attests to cold's having greater influence on complex, rather than simple, cognition (Allen & Fisher, 1978; Baddeley, 1966; Ellis, 1982; Ellis, Wilcock, & Zaman, 1985; Enander, 1987; Enander & Hygge, 1990; Giesbrecht, Arnet, Vela, & Bristow, 1993; Hartley & McCabe, 2001; Hoffman, 2001; Palinkas, 2001; Pilcher et al., 2002; Thomas et al., 1989; Wyndham, 1969; for meta-analyses, see Færevik 2010; Pilcher et al., 2002). One study found that high motivation can offset the cognitive consequences of cold (Lana, Liana, Pana, & Yeb, 2009).

Attention Control – Both Hot and Cold Reduce attention Control

Heat and Attention Control

Several studies indicate that heat reduces attention control (Bell, Provins, & Hiorns, 1964; Benor & Shvartz, 1971; Epstein, Keren, Moisseiev, Gasko, & Yachin, 1980; Mackworth, 1950; Mortagy, 1971; VanBuskirk 2011; Viteles & Smith, 1946; for a meta-analysis, see Pilcher et al. 2002; for a review, see Hancock, 1986; cf. null findings of Howarth & Hoffman, 1984; Gaoua, Racinais, Grantham, & Massioui, 2011). Heat has been found to reduce monitoring, tracking, and vigilance (Echeverria, Barnes, & Bittner, 1991) and performance on a Wilkinson visual vigilance type test (Poulton & Edwards, 1974). One study found that heat narrowed attention (Bell, 1981). Heat reduced sustained attention on a military command task

(Fine & Kobrick, 1978). Driving an automobile requires sustained attention control (Brown, 1967), and most automobile accidents occur in the summer (U.S. Department of Transportation, 2012).

Familiarity with an attention control task has been found to either attenuate (Mackworth, 1950) or reverse (Colquhoun & Goldman, 1972) the effect of heat. These findings are in line with the idea that heat reduces self-control, which is required little for habitual, learned responses. Further, some work suggests that heat impairs primarily complex, rather than simple, forms of attention control (Carlson, 1961).

Cold and Attention Control

Several studies indicate that cold reduces attention control (Brewer, 2012; Enander & Hygge, 1990; Færevik, 2010; Kissen, Reifler, & Thaler, 1964; Lockhart, 1971; Mackworth, 1997; O’Connor, Hyde, & Clarke, 2009; Payne, 1959; Pepler, 1958; Ramsey, 1983; Russell, 1957; Teichner & Kobrick in 1955; Teichner & Wehrkamp, 1954; Vaughan, 1977; for a meta-analysis, see Pilcher et al. 2002; for reviews, see Grether, 1973; Hancock, 1984, 1986; Kobrick & Fine, 1983; Ramsey, 1983; cf. null findings of Baddeley et al., 1975; Egstrom, Weltman, Baddeley, Cuccaro, & Willis, 1972; Færevika & Reinertsena, 2003; Teichner, 1966;). Cold (e.g., immersion in cold water, Davis, Baddeley, & Hancock, 1975; Doubt et al., 1989; Giesbrecht, Arnett, Vela, & Bristow, 1993) is known to reduce vigilance (Banderet & Lieberman, 1989; Hancock & Vasmatzidis, 2003; Mackworth, 1950), tracking ability (Fox, 1967; Provins & Clarke, 1960), monitoring (Davies & Parasuraman, 1982), and watchkeeping (Poulton, Hitchings, & Brooke, 1965), and to increase distractibility (Færevik, 2010; Makinen, Palinkas et al. 2006).

Experiencing arctic temperatures regularly has been found to reduce performance on the Wilkinson visual vigilance task (Angus, Pearce, Buguet, & Olsen, 1979). Shipboard lookouts who experience cold often become less vigilant (Poulton et al. 1965). Patients experiencing winter seasonal affective disorder show reductions in attention control (Merikanto et al., 2012). Attentional set shifting was impaired in rats exposed chronically to cold (4 °C). Cold has been found to impair performance on a sentry duty task (Adam et al., 2008). An analysis of nearly 9,000 errors from attentional oversight made by 140 bank clerks in New York City from 1896 to 1897 indicated that most errors occurred during the winter (Dexter, 1904). Some work indicates that cold is especially likely to reduce complex, or more demanding, forms of attention control (Enander, 1987; Hartley & McCabe, 2001).

In sum, both hot and cold reduce attention control. Findings include both laboratory work that establishes causality and field work that establishes external validity. Moderation is in line with the idea that heat and cold reduce self-controlled attention.

Aggressive Restraint

Heat is related to increased aggression. Cold might be too.

Heat and Aggressive Restraint

A large body of work establishes a relationship between heat and increased aggression (Block, 1984; Brunsdon et al, 2009; Bushman, Wang, & Anderson, 2005; Cohen, 1941; DeFronzo, 1984; Dexter, 1899; Hakko, 2000; Harries, 1980-1981; Harries & Stadler, 1983; Howarth & Hoffman, 1984; Jacob & Lefgren, 2003; McLean, 2007; Michael & Zumpe, 1983; Palamerek & Rule, 1980; Ranson, 2012; Read, 2006; Rosario, 2006; Rotton & Frey, 1985; Schwartz, 1968; Volpea, Tavaresb, & Del Portoc, 2008; for reviews, see Anderson, 1989; Anderson & Anderson, 1998; Anderson, Anderson, Dorr, DeNeve, & Flanagan, 2000;

Baumer & Wright, 1996; Bell, 1981). Heat is associated with increases in a variety of aggressive behavior, including homicide (Lester, 1987), assault (Rock, Judd, & Hallmayer, 2008; Simister, 2008), robbery (Sorg & Taylor, 2011), and domestic violence (Auliciems & DiBartolo, 1995; Cohn, 1993; Rotton & Frey, 1985). The relationship between heat and high aggression has been observed in locations throughout the globe (e.g., in Singapore, Pakiama & Lima, 1984; Finland, Hakko, 2000; Hakko, Räsänen, & Tiihonen, 1998; India & Pakistan, Simister, 2002; Italy, Sisti, Rocchi, Macciò, & Preti, 2011; the United States, Nisbett, 1993; Rosenfeld, 1986; England and Wales, Field, 1992; the Southern Hemisphere, Lima, 1998; Beato et al., 1999). When it is hot, aggression is more likely (Baumer & Wright, 1996; Butke, Scott, & Sheridan, 2010; Ceccato, 2005; Gorr et al., 2001; Hakko, Räsänen, & Tiihonen, 1998; Hipp, Bauer, Curran, & Bollen, 2004; Lasnier, Brochu, Boyd, & Fischer, 2010; Lester, 1979; Thomas, Shaffer, Rzucidloc, Shirkc, & Dias, 2007).

There have been more civil wars in Sub-Saharan Africa during hotter years (Burke, Miguel, Satyanath, Dykema, & Lobell, 2009). More gun shots are fired in June (Cohen, Gorr, & Durso, 2003). An analysis of FBI archival data from 1976 to 1998 that included over 23,000 cases of child homicide indicated that most occurred in the summer (Mccleary & Chew, 2002; see also Laskey, Thackeray, Grant, & Schnitzer 2010). Abuse toward women by a cohabitating male is most likely in the summer (Michael & Zumpe, 1986), and hospital admissions related to assault are highest in the summer (Shepherd, Ali, Hughes, & Levers, 1993; Sivarajasingam & Shepherd, 2001). Focus group studies indicate extremely high levels of aggression among Native Americans of Arawak origin in Venezuela (Seale et al. 2010). Violence and murder increase during heat waves (Merino, Mateu, Torrens, San Gil, & Cunillera, 2009; Flannery & Penk, 1993; Mathur, 1994). Violent suicides are especially likely in the summer (for a review, see Christodoulou, Efstathious, Bouras, Korkoliakou, & Lykouras, 2012). Riots occur when it is hot (Cohen, 2011; United States Riot Commission, 1968). In one study, juveniles in a heat chamber became more aggressive (Rohles, 1967). Heat has been found to increase assault in prison (Megargee, 1977; Sylvester, Reed, & Nelson, 1977). Police are more aggressive and are more likely to shoot at suspects when it is hot (Vrij, Van Der Steen, & Koppelaar, 1994). Heat is associated with increased automobile horn honking (Kenrick & MacFarlane, 1984). Major league baseball pitchers are more likely to hit batters when it is hot (Reifman, Larrick, & Fein, 1991), especially if they have been provoked by their teammates having been hit, suggesting reduced aggressive restraint (Larrick, Timmerman, Carton, & Abrevaya, 2011). Air conditioners reduce road rage, assault, and murder (cf. Diamond, 2011; Rotton & Cohn, 2004). Experimental work that manipulated room temperature showed that hostile affect and thought increase in hot, versus thermoneutral, temperatures (Anderson, Anderson, & Deuser, 1996). Cognitive-semantic associations also support a heat-aggression link (Bradbury & Zamoa, 2011; Bushman & DeWall, 2009; Rule, Taylor, & Dobbs, 1987; Wilkowski, Meier, Robinson, Carter, & Feltman, 2009).

Other organisms are more aggressive when it is hot. Spiders, for instance, show increased attack of prey and conspecifics in the heat (Pruitt, Demes, & Dittrich-Reed, 2011). This relationship has been found among rats (Berry & Jack, 1971), fish (Biro, Beckmann, & Stamps, 2010; Magoulick & Wilzbach, 1998), snakes (Schieffelin & de Queiroz, 1991; Brodie & Russel, 1999), lizards (Crowley & Pietruszka, 1983), insects (Wallis, 1964), and other vertebrates (Cutts et al. 1999, 2001; McCarthy, 2001) and invertebrates (Brown et al. 2003; Ketola & Kotiaho 2010).

Two patterns have been found to describe the relationship between heat and aggression. Whereas the bulk of studies support a positive linear relationship between temperature and aggression (Anderson, 1987, 1989; Anderson & Anderson, 1996; Anderson & Anderson, 1998; Anderson, Anderson, Dorr, DeNeve, & Flanagan, 2000; Anderson, Anderson, & Deuser, 1996; Anderson, Bushman, & Groom, 1997; Baron & Bell, 1975; Baron & Bell, 1976; Bell & Fusco, 1989; Boyanowsky, 1999; Boyanowsky, Calvert-Boyanowsky, Young,

& Brideau, 1981; Burke, Miguel, Satyanath, Dykema, & Lobell, 2009; Bushman, Wang, & Anderson, 2005; Butke & Sheridan, 2010; Carlsmith & Anderson, 1979; Cohn, 1990a, 1990b; Cohn & Rotton, 1997, 2000; Cotton, 1986; Field, 1992; Haertzen, Buxton, Covi, & Richards, 1993; Harries & Stadler, 1988; Hayashi, 2006; Horrocks & Menclova, 2011; Jacob, Lefgren, & Moretti, 2006; Kenrick & MacFarlane, 1984; Lab & Hirschel, 1988; Levine, Stoloff, & Spruill, 1976; Perry & Simpson, 1987; Ranson, 2012; Reifma et al., 1991; Vrij et al., 1994; Rotton & Cohn, 2003; Rotton & Frey, 1985; Simister, 2008; Simister & Cooper, 2005; Simister & Van der Vliert, 2005; Wilkowski, Meier, Robinson, Carter, & Feltman, 2009; Michael & Zumpe, 1983a, 1983b), a substantial number of studies support a curvilinear aggression, indicating that aggression peaks (roughly) around 28° C and reduces as temperature increases or decreases from that temperature (Anderson & DeNeve, 1992; Baron & Bell, 1976; Baron & Pansberger, 1978; Bell, 1992; Cohn, 1990; Gamble & Hess, 2012; Hayashi, 2006; Lagace-Seguin & d'Entremont, 2005; Peng, Xueming, Hongyong, & Dengsheng, 2011; Rotton & Cohn, 2000, 2004; van de Vliert, Schwartz, Huismans, Hofstede, & Daan, 1999). The idea that temperatures above 28° C are associated with reduced aggression is inconsistent with the idea that heat reduces the self-controlled restraint of aggression. The common explanation for the curvilinear findings, however, is that high heat is associated with low aggression because there are fewer opportunities for aggression.

Some studies have, however, found that aggression is high in high heat, consistent with the bulk of evidence demonstrating a positive linear relationship between temperature and aggression. In the laboratory, high heat has been found to produce aggression (e.g., shock, Anderson, 1989; Baron & Bell, 1976). High heat has been linked to homicide (DeFronzo, 1984; Simister, 2002) and riots (Leishman, 2002). An observational study of Baboons in the zoo found that the most, and most intense, aggression occurred at high temperatures (Grow & Nash, 2004).

Moderation of the heat-aggression relationship is consistent with the idea that heat reduces the self-controlled restraint of aggression. Heat is less likely to produce riots in countries to the extent that aggressive restraint and self-control are culturally valued and proscribed (Bjorklund & Kipp, 1996; van de Vliert et al., 1999; Woodburn, 1988). Heat may demonstrate a stronger relationship among people who have other depleting demands (Breetzke & Cohn, 2011; Harries, 1989; Harries, Stadler, & Zdorkwski, 1984; Harries & Stadler, 1988; cf. Sorg & Taylor, 2011).

Cold and Aggressive Restraint

The findings that show a positive linear relationship or curvilinear relationship between heat and aggression suggest that aggression is lowest in the cold. There is reason to believe, however, that cold increases aggression. First, several factors may limit aggression in the cold. People more easily cope with cold than heat and there may be fewer opportunities for aggression in the cold (e.g., public squares are crowded in the summer but not the winter). Cumbersome clothing may limit aggressive acts. Secondly, findings that demonstrate a null relationship between temperature and aggression may occur because the effects of both heat and cold are obscured. Because both cold and heat increase aggression, researchers may fail to notice the relationship between temperature and aggression. Third, there is evidence that cold increases aggression. This evidence takes three forms, showing that a) cold has is linked to aggression, b) experimental manipulations of cold increase aggression, and c) extreme cold relates to increased aggression.

Some studies link cold to increased aggression (Block, 1979, as cited in Block, 1984; Bell & Baron 1977). Aggression (e.g., murder, robbery) has been found to be high in winter months, across a variety of locations (the United States, Block, 1984; Cheatwood, 1988; Gorr, Olligschlaeger, & Thompson, 2003; Simister & Cooper, 2005; Israel, Landau & Fridman, 1993; Italy, Sisti et al., 2011; Pakistan and India, Simister, 2002). One study found high numbers of assault patients in an emergency department in December (Shepherd, Ali, Hughes, & Levers, 1993). An analysis of over 20 years of data demonstrated high rates of murder and robbery in the winter (Vujic, 2009). Analyses of FBI data from over 23,000 cases from 1976-1998 revealed infant and toddler homicide to be high in winter (Mccleary & Chew, 2002; replicated by a nonsignificant trend, see Laskey, Thackeray, Grant, & Schnitzer, 2010). Sivarajasingam, Corcoran, Jones, Ware, and Shepherd (2006) demonstrated that violence related injury is high in winter. Interviews of roughly 100,000 victims indicated that many robberies occurred in December (Dodge, 1988). Days colder than 0°C are associated with high levels of robbery (DeFronzo, 1984). Cold elicited increases in missle fire among military members completing a simulation (Enander, 1998). In Pennsylvania, October (but not other winter months) was associated with high rates of hospital admission for physical child abuse (Thomas, Shaffer, Rzucidloc, Shirkc, & Dias, 2007). Hippocrates noted higher levels of aggression in Northern than Southern Greece (Millar, 2008). Poaching is high in winter (Osborne, 2000).

Two experimental studies suggest that cold causes increases in aggression. In one, cold increased hostility and hostile attitudes (Anderson, Anderson, & Deuser, 1996). In the other, aggression increased among angered subjects exposed to 7.22°C ambient temperature (Boyanowsky et al., 1981-1982).

Extreme cold is linked to increased aggression. Some work showed that people in temperatures between -8°C and -28°C report increased aggressive feelings (Howarth & Hoffman, 1984). Violent crimes are more common in Norway during October and November (Morken & Linaker, 2000). Greenland is the coldest Nordic country, and it has the most homicide, which is often caused by impulsivity (Björkstén, Kripke, & Bjerregaard, 2009). Anger and aggression are common in Antarctica (Sandal, Leon, & Palinkas, 2006; Shea, Slack, Keeton, Palinkas, & Leveton, 2011). Family violence is frequent among natives in Alaska (Seale, Shellenberger, & Spence, 2008).

Criminal Restraint

Both heat and cold are associated with increased crime.

Cold and Criminal Restraint

Many scholars have noted that crime increases when it is cold. Property crimes tend to be higher when and where it is cold (Baumer & Wright, 1996; Champeneouf 1821-1835, as cited in Lewis & Alford, 1975; Gorr et al., 2003; Guerry, cited in Brearley, 1932; Hird & Ruparel, 2007; Levine, Stoloff, & Spruill, 1976; Levine et al., 1976; Lewis & Alford, 1975; Lombroso, 1918). Cold is associated with increases in larceny (motor vehicle theft, shop theft), burglary (domestic burglary), and vehicle interference and tampering (Cohen, 1941; Cohen, Gorr, & Durso, 2003; Cohn & Rotton, 2000; Dodge, 1988; Falk, 1952; Henry & Bryan, 2000; Hird & Ruparel, 2007; Vujic, 2009; Yee Yan, 2004). Months such as April and September have been found to have the fewest crimes (Aschaffenburg, 1903/1913, as cited in Anderson, 1989). Dexter (1904) found a negative linear relationship between temperature and problems in a penitentiary (suggestive of rule breaking) with temperatures below -3.89°C. Farrell and Pease (1994) found that most calls to the police for burglary and motor vehicle theft ocurred in winter. Sheep-stealing in Wales from 1730 to 1830 was high in Winter and lowest in the Spring (Woodward, 2008).

Heat and Criminal Restraint

A large number of crimes – property crimes, disorderly conduct, public nuisance, drifting, panhandling, burglary, larceny (e.g., theft of motor vehicles, bicycles), arson, harassment, going equipped for stealing – are committed during the summer (Block, 1984; Cohn & Rotton, 2000; Cohen, Gorr, & Durso, 2003; Gorr, Olligschlaeger, & Thompson, 2003; Hird & Ruparel, 2007; Lasnier, Brochu, Boyd, & Fischer, 2010; Vujic, 2009; see also Field, 1992; Cohn 1990a, 1990b; Rotton & Cohn, 2003). One study found that rule breaking in prison peaked during hot summer months (Haertzen, Buxton, Covi, & Richards, 1993). Robbery, burglary, and larceny are more common in the Southern, rather than Northern, United States (Anderson, 1989; note that this pattern may be inconsistent with the aforementioned findings on cold). Sheep-stealing is high during the summer (Woodward, 2008). Dexter (1904) found that patients in a mental hospital behave worse when it is hot. One study found that arson increased in heat primarily among people of low socioeconomic status (Corcoran, Higgs, & Chhetri, 2011).

Passivity

Passivity is greatest with cold. High heat relates to passivity.

Cold and Passivity

Cold is associated with reduced physical activity (Anderson, 1989; Bell, 1981; Givoni et al. 2003; Eliasson, Knez, Westerberg, Thorsson, & Lindberg, 2007; Kenny, Warland, Brown, & Gillespie, 2009; Pivarnik, Reeves, & Rafferty, 2003; Rotton, 1985; Rotton, Shats, & Standers, 1990; Yang, Roux, Bingham, & 2011; cf. Phithakkitnukoon, Leong, Smored, & Olivier, 2012; Rotton & Shats, 1990), likely the result of lowered core body temperature (Enander, 1989; Ramsey, 1983). People walk slower when it is cold (Rotton, 1985), and the lowest numbers of people cycle when it is colder (Brandenburg, Matzarakis, & Arnberger 2004, 2007; Gallop, Tse, & Zhao, 2012; Hanson & Hanson, 1977; Lewin, 2011; Miranda-Moreno & Nosal, 2011; Niemeier, 1996; Richardson, 2000; Tin Tin, Woodward, Robinson, & Ameratunga, 2012). One study found that current, rather than forecasted, weather dictated decisions to cycle, suggesting an influence of temperature (Tin Tin et al., 2012). Fewer people use running tracks when it is colder (Suminski, Poston, Market, Hyder, & Sara, 2008). Children have been found to be more physically passive when it is cold (Kolle et al., 2009; Silva, Santos, Welk, & Mota, 2011). One thorough review demonstrated that a large number of studies converge on the hypothesis that cold reduces physical activity (Chan & Ryan, 2009).

Snow has been found to reduce election voter turnout (Gomez, Hansford, & Krause, 2000). Television watching increases when it is cold (Eisinga, Hans, Franses, & Vergeer, 2011; in the United States, Barnett, Chang, Fink, & Richards, 1991; Comstock, Chaffee, Katzman, McCombs, & Roberts, 1978; Gensch & Shaman, 1980; in Europe, Barwise & Ehrenberg, 1988; Roe & Vandebosch, 1996). Winter seasonal affective disorder is associated with hypersomnia (Øyane, 2010). There are more school absences at colder temperatures (Coleman & Schaefer, 1990; Dexter, 1904).

The influence of cold on passivity may not be limited to humans. Passivity may be greater in cold among spiders (Pruitt, Demes, & Dittrich-Reed, 2011), insects (Wallis, 1964), fish (Magoulick & Wilzbach 1998; Biro et al. 2010), snakes (Schieffelin & de Queiroz 1991; Brodie & Russel 1999), lizards (Crowley & Pietruszka 1983), and other organisms (Brown et al. 2003; Cutts et al. 1999, 2001; Ketola & Kotiaho, 2010; McCarthy 2001).

Cold has been found to reduce recreational, more than commuting, cycling (Brandenburg et al., 2004). Recreational cycling may require more self-control, whereas individuals have less personal control over whether to cycle for the commute.

Heat and Passivity

Findings on cold and passivity indicate that people are not passive in the heat. There are, however, some findings that link heat to passivity (Givoni et al. 2003; Eliasson, Knez, Westerberg, Thorsson, & Lindberg, 2007; Kenny, Warland, Brown, & Gillespie, 2009). Heat is associated with reduced productivity (Fine & Kobrick, 1987) and duration of cellular telephone calls (Phithakkitnukoon, Leong, Smoreda, & Olivier, 2012). School attendance is lower when it is hot (Dexter, 1904). Participants in one study, who wore electronic physical activity monitors, took fewer steps on hotter days (Togo, Watanabe, Park, Shephard, & Aoyagi, 2005). Temperatures near 30° C are associated with reduced cycling (Lewin, 2011; Neimer, 1996; Richardson, 2000; Thomas, 2008; cf. Brandenburg, Matzarakis, & Arnberger, 2004). In the United Arab Emirates, high heat may reduce physical activity (Henry, Lightowler, & Al-Hourani, 2004). Children in the Southern United States show less physical activity in the summer (Baranowski, Thompson, DuRant, Baranowski, & Puhl, 1993). In Arizona, Baboons have been observed to become passive at temperatures over 37.78°C (Grow & Nash, 2004).

Physical Persistence

Heat reduces physical persistence. It is well-established that heat reduces physical persistence (Cheuvront, Kenefick, Montain, & Sawka, 2010; Ely, Cheuvront, Kenefick, & Sawka, 2010; Galloway & Maughan, 1997; González-Alonso & Calbet, 2003; González-Alonso et al., 1999a; Nielsen, 1996; Nielsen & Nybo, 2003; Nybo et al., 2001; Parkin et al. 1999; Schlader, Stannard, & Mündel, 2011; cf. Periard, Cramer, Chapman, Caillaud, & Thompson, 2011). Participants in a 35°C, versus 29°C, water-perfused suit persisted nearly only half as long on a physical task (MacDougal, Reddan, Layton, & Dempsey, 1974). Repetitive jumping was reduced among soccer players in the heat, versus thermoneutral temperatures (Mohr & Krustrup, 2012). Cycling persistence - in both the laboratory and field - is reduced in heat (Ely, Cheuvront, Kenefick, & Sawka, 2010). Precooling attenuates declines in persistence in the heat (Duffield, Green, Castle, & Maxwell, 2010). Above a certain core body temperature, humans and nonhuman animals cease to persist (Fuller et al., 1998; González-Alonso et al., 1999b; Nielsen et al., 1993; MacDougal et al., 1974; Nybo, 2008; Walters, Ryan, Tate, & Mason, 2000; see also Hasegawa et al., 2008).

Many researchers have argued that reductions in physical persistence in the heat are due to central fatigue and a voluntary cessation of effort (Maughan, 2010; Nybo, 2008; Noakes, 1998; Noakes et al., 2005) - a phenomenon akin to depletion of self-control resources. Heat has been found to reduce physical persistence more than the ability to briefly generate force (Nybo, 2008; Nybo & Nielsen, 2001), which suggests a self-control component.

Further support for the idea that heat reduces self-control comes from a study by de Jonge, Thompson, Chuter, Silk, and Thom (2012). They found that heat (32°C) and humidity reduced physical persistence primarily when women were in the luteal phase of the menstrual cycle – a time when self-control is reduced (Gailliot et al., 2010).

Cold might be related to decrease physical persistence (Holmér, 2009; O'Brien, Tharion, Sils, & Castellani, 2007). Research in the field and laboratory suggest that below or above 12°C, persistence declines (Castellani, Carter, Adam, & Cheuvront, 2009).

Sexual Restraint

Heat and cold are associated with signs of decreased sexual restraint.

Heat and Sexual Restraint

Sex crime, such as sexual assaults and rape, is more common when and where it is hot (Anderson, 1987; Bicakova-Rocher, Smolensky, Reinberg, & De Prins, 1985; Cohen, 1941; Cohn, 1990a, 1990b, 1993; de Fronzo, 1984; Field, 1992; Keating, Higgs, Willott, & Stedman, 1990; Leffingwell, 1892; Lombroso, 1918, as cited in Haertzen et al., 1993; McDermott, McBride, & Lee-Gorman, 2008; Perry & Simpson, 1987; San Gil, González, & González, 1988, 1994; Vujic, 2009; for a nonsignificant trend, see Anderson, Bushman, & Groom, 1997). Temperature correlates positively with sex crime (Bureau of Justice Statistics, 1988; Dodge, 1988; Field, 1992; Hagelin et al., 1999; Hird & Ruparel, 2007; McLean, 2007; Micheal & Zumpe, 1983a, 1983b; Phithakkitnukoon, Leong, Smoreda, & Olivier, 2012; Perry & Simpson, 1987). Sex crime has been found to increase around temperatures of 25°C (Simister, 2002). An analysis of nearly 12,000 cases of sexual abuse over 12 years in Chile (Southern Hemisphere) indicated a peak in November (Télleza, Galleguillos, Aliaga, & Silvac, 2006). The number of hospital sexual assault victims has been found to peak between June and August (Chung et al., 2009). One study of England and Wales found a lack of seasonality for rape of a male (Cohen, 1941).

There are high rates of coitus and sexual activity in the early summer (Fortenberry, Orr, Zimet, & Blythe, 1997; Macdowall et al., 2007; Petersen & Alexander, 1992; Warren, 1980). Such seasonality may be caused by temperature (Chang et al., 1963; Roenneberg & Aschoff, 1990). Rates of conception are high in summer (Cummings, 2012; James, 1990; Smits, 1998; Kevan, 1979; Silm, 2009; Trovato & Odynak, 1993), suggesting plausibility of increases in unrestrained sexual acts. In the United States, temporal preferences for conception, and actual occurrence of, are the opposite (Rodgers & Udry, 1988). A peak in abortions occurs in late summer (Macdowall, Wellings, Stephenson, & Glasier, 2007), suggesting prior lack of sexual restraint. Rates of sexually transmitted diseases are high after early summer (Herold, 1993; Schroeder, Tetlow, Sanfilippo, & Hertweck, 2001; Macdowall et al., 2007; Wellings, 1999), which may be a result of self-control failures to use condoms or avoid risky sex.

Many people lose their virginity in the summer (Leven, Xu, & Bartkowski, 2002; Macdowall et al., 2007; Pittman, Tita, Barratt, Rubin, & Hollier, 2005; Rodgers, Harris, & Vickers, 1992). Half of the college students in Israel who completed a questionnaire reported having lost their virginity in the summer (Barak, Stein, Ring, Ticher & Elizur, 1997). Given that people sometimes use self-control to delay initial intercourse, loss of sexual restraint may be involved. Increases in summer (and winter) conception may occur more among people with other depleting demands (Becker, 1991; Chowdhury, 1972; Kestenbaum, 1987; Lam & Miron, 1991; Pasamanik, Dinitz, & Knoblock, 1959, 1960; Rosenberg, 1966; Seiver, 1985, 1989; Warren & Tyler, 1981; cf. Zelnick, 1967; Udry & Morris, 1967).

Cold and Sexual Restraint

Sex crime might be less likely when fewer people are outside. Indecent sexual behavior against women has been found to be high in February (Bicakova-Rocher, Smolensky, Reinberg, & De Prins, 1985). Cold increased sexual humor among sensation seekers (Zuckerman, 1994). Including women in wintering-over groups in Antarctica leads to sexual harassment (Rosnet, Jurion, Cazes, & Bachelard, 2004). Conception (Becker, 1991; Cesario, 2002; Cummings, 2012; James, 1990; Kestenbaum, 1987; Haandrikman & Van Wissen, 2008; Lam & Miron, 1991; Macdowall et al., 2007; Rosenberg, 1966; Seiver, 1985, 1989; Silm, 2009; Smits, 1998; Trovato & Odynak, 1993; cf. Leridon, 1986), coitus and sexual activity (Fortenberry, Orr, Zimet, & Blythe, 1997; James, 1971; Petersen & Alexander, 1992; Warren, Gold, Tyler, Smith, & Paris, 1980), and loss of virginity (Leven, Xu, & Bartkowski, 2002; Macdowall et al., 2007; Pittman, Tita, Barratt, Rubin, & Hollier, 2005; Rodgers, Harris, & Vickers, 1992) are common when it is cold. Temperature may cause seasonal changes in sexual activity (Chang et al., 1963; Roenneberg & Aschoff, 1990).

Winter holiday conceptions may be unplanned, spontaneous, and attributable to reduced contraceptive use (Kevan, 1979). Winter conceptions, more generally, may often be unintended (Rodgers & Udry, 1988). The Winter holiday season is followed by an increase in abortions (Wellings, Macdowall, Catchpole, & Goodrich, 1999; Elam-Evans, Strauss, Herndon, Parker, whitehead, & Berg, 2002; Macdowall et al., 2007; Parnell & Rodgers, 1998; Warren, Gold, Taylor, Smith, & Paris, 1980). Rates of sexually transmitted diseases increase after winter (Herold, 1993; Schroeder, Tetlow, Sanfilippo, & Hertweck, 2001; Wellings et al., 1999).

Work Regulation – Heat is associated with Reduced Work

Heat is linked with reduced work productivity (Bandyopadhyaya, 1978; Fine & Kobrick, 1987; Frese, 1987; Kjellstrom, Kovats, Lloyd, Holt, & Tol, 2008; Myrdal, 1968; Van Dormolen, Hertog, Van Dijk, Fortuin, 1988). The work rate reduces with hyperthermia (Cheung & Sleivert, 2004). Productivity has been found to decline among plant workers in temperatures over 29°C (see Bessamaire, 2006). In a 30°C, versus 22°C, office, participants were less willing to exert effort on tasks (Lan, Wargocki, Wyon, & Lian, 2011). Students worked less on hot days (Dexter, 1904). Reduced productivity has been noted on hot days among patients in a mental hospital (Dexter, 1904). In South Africa, work regulation is difficult when temperatures exceed 40°C (Mathee, Oba, & Rose, 2010). In the heat, cooling suits have been found to increase productivity (Furtado, Craig, Chard, Zaloom, & Chu, 2007). Polls indicate that many people believe that heat reduces their work productivity and that some do not feel like working when it is hot (Earth magazine, 2011; Stewart, 2011). People seem to lack resources to meet work demands when it is hot (Burke, Miguel, Satyanath, Dykema, & Lobell, 2009, cf. for cold). With respect to cold, personnel in Antarctica report reduced work output (Sandal, Leon, & Palinkas, 2006).

Intake Regulation

Heat and cold are associated with increased alcohol intake, and heat with increased tobacco use.

Heat and Alcohol

Though a few findings argue against increased alcohol consumption in heat (or cold; Bulbena et al., 2009; Huang, Schildhaus & Wright, 1999; Lemmens & Knibbe, 1993; Parker & Tavassoli, 2000; Silm & Ahas, 2005), the majority of located findings support a positive association. Heavy drinking has been found to be high during summer (Cho, Johnson, & Fendrich, 2001; Fitzgerald & Mulford, 1984; San Gil, González, González, 1988, 1994; Uiterbroek, 1996), as is drinking amongst teenagers (Tavassoli, 2009). In Estonia, summer is a time of beer consumption, as indicated by various measures, and high temperature has been implicated as a mediator (Silm, 2009; Silm & Ahas, 2005). High temperatures during the summer account for high beer demand during the late 19th and early 20th century in Germany and Prussia (Traxler & Burhop, 2010). Heat waves may increase beer sales (British Beer and Pub Association, 2003) and alcohol abuse (Bulbena et al., 2009), suggesting causality of temperature. Alcohol consumption (and alcohol poisoning) is high on Midsummer Day in Finland (Poikolainen, Lappanen, & Vuori, 2002) and the 4 th of July in the United States (Poikolainen et al. 2002; Silm & Ahas, 2005; Speer et al., 1998; see also Mintel, 2003). More alcohol is consumed during hotter years (Bushman & Cooper, 1990). Crime and automobile accidents related to drunk driving increased when it was hot, during the summer (Silm, 2009; Silm & Ahas, 2005). Over 88% of men and 17% of women who are Native Americans of Arawak origin living in Venezuela have been found to exhibit problem drinking, linked to loss of control and failure to meet obligations (Seale et al., 2010). Sexual assault is highest in Ireland during the summer, and many cases involve alcohol consumption (McDermott, McBride, & Lee-Gorman, 2008). Most people have their initial drink of alcohol in the summer (Office of Applied Statistics, 2004).

Cold and Alcohol

Cold is associated with increased alcohol intake. Alcohol consumption, poisonings, and sales are high in Winter, especially during the holidays, in Europe and North America (Cho, Johnson, & Fendrich, 2001; Lemmens & Knibbe, 1993; Poikolainen et al., 2002; Silm, 2009; Silm & Ahas, 2005; Speer, Gorman, Labouvie, Ontkush, & 1998; Uitenbroek, 1996; cf. Björkstén, Kripke, Bjerregaard, & 2009). Teenagers drink more alcohol in the winter (Tavassoli, 2009). Alcohol consumption is higher in higher latitudes (Parker & Tavassoli, 2000). Vodka and wine consumption is high in Estonia during a few of the winter months (Silm, 2009; Silm & Ahas, 2005). Greenland is the coldest Nordic country, and its high levels of homicide are primarily due to alcohol consumption (Gudjonsson & Petursson, 1990). Binge drinking, blackouts, and alcohol abuse and dependence are relatively high in Alaska among natives (Alaska Federation of Natives, 1989; Anchorage Daily News, 1989; Alaska Natives Commission, 1994; Brems, 1996; Denny, Holtzman & Cobb, 2003; Kroliczak, Chattopadhyay, & Larsen, 1999; Miller et al., 2002; Segal, 1991, 1999; Segal & Hesselbrock, 1997; Seale, Shellenberger, & Spence, 2008; Shore, Manson, & Buchwald, 2002; Stillner, Kraus, Luekefeld & Hardenbergh, 1999; Zebrowski & Gregory, 1996).

Tobacco

Of the few located findings on tobacco, the majority link heat to greater tobacco use. Temperature is positively associated with rates of cigarette smoking and nicotine dependence (Etcheverrya, Agnewa, & Newberry, 2012; Momperousse, Delnevo, & Lewis, 2007). Cigarette sales are high in summer (Chandra & Chaloupka, 2003; Momperoussee et al., 2007). Smoking initiation among youths is typical in summer (Colwell et al., 2006; Wellman & DiFranza, 2003). One finding supports a null relationship between seasonality and cigarette use (Huang, Schildhaus, & Wright, 1999). Another provides contradictory evidence (lower tobacco use in hotter latitudes, Parker & Tavassoli, 2000).

Other Findings

It is plausible that helping is highest at middle temperatures. Helping an interviewer and monetary tipping of waitresses has been found to be highest at 19°C (Cunningham, 1979). Heat has been found to reduce helping (Bell, 2010; Page, 1978; see also Kolba, Gockelb, & Wertha, 2012). Preschool children scoring high in negative affect were rated by teachers as less prosocial when it was cold (Lagace-Seguin d'Entremont, 2005). Polar expeditions are sometimes marked by problems between women and men (Palinkas, 1992), emphasized group differences (Rosnet, Jurion, Cazes, & Bachelard, 2004), isolation (Sandal, 2000), and stereotyping (Leon, McNally, & Ben-Porath, 1989).

Mediation of the Relationship between Temperature and Self-Control

Emotion Regulation

Heat reduces positive emotion. Cold is associated with less positive emotion.

Heat and Emotion Regulation

Numerous studies establish that mood worsens in heat (Bell & Baron, 1977; Cohn, 1993; Connolly, 2012; Griffitt, 1970; Griffitt & Veitch, 1971; Goldstein, 1972; Keller et al., 2005; Pray, 2011; Rehdanz & Maddison, 2005; Tsutsui, 2012). The body of evidence is diverse. It includes experimental work, field studies, country data, longitudinal studies, and physiological measures. Heat increases strain and negative mood (Goldstein, 1972; Mawson, 1999), discomfort (Anderson, 1989; Baron & Bell, 1976; Bell, 2010; Griffitt, 1970), and irritability and frustration (Frese, 1987; Johnson & Kobrick, 2001). Likewise, air conditioners increase comfort (Diamond, 2011). Discomfort increases and mood decreases around 27°C (Stewart, 2011). People complain often of summer heat (Tsutsui, 2012). A study of over 40,000 Thai workers showed that working in heat increases stress (Tawatsupa, 2010). Chemical warfare clothing increases stress and decreases mood, likely due to increases in body temperature (for an extensive review, see Taylor & Orlansky, 1993). Happiness, subjective well-being, and life satisfaction are lower in hotter countries (Diener & Diener, 1994; Maddisina, 1981-2008; Rehdanz & Maddison, 2005). Participants in one study completed the Positive and Negative Affect Schedule on multiple days. Higher temperatures correlated with more negative affect (Denissen, Butalid, Penke, & van Aken 2008). People in the United States Mid- and South-Atlantic regions (where it is hot) scored higher on self-ratings of nervous and worrying than did people in other geographic regions (Plaut, Markus, & Lachman, 2002). Customers find high temperatures in stores to be irritating (D'Astous, 2000). Functional magnetic resonance imaging measures have shown that warm stimulation increases activity in brain regions underlying affect and emotion (Sung, Yoo, Yoon, Oh, Han, & Park, 2007).

Heat is associated also with severe increases in negative emotion. A study of hospital admissions in South Australia from 1993 to 2006 indicated that mood and stress disorders are more prevalent when temperatures exceed 26. 7°C. Hospital admissions for depression increased when temperatures exceeded 24.0°C (Sung, Chen, & Su, 2012). Depression when it is hot – a summer seasonal affective disorder (Agumadu et al., 2004; Huibers et al., 2010) – is common in Australia (Morrissey, Raggatt, James, & Rogers, 1996), Asia (Øyane, 2010), Vietnam (Nguyen & Tokura, 2002), and Taiwan, Brazil, and India (Page, 2011). It is hotter in India than in Italy, and summer seasonal affective disorder is more common in India (Tonettia, Sahub, & Natalea, 2012).

A few experimental studies suggest that heat causes deteriorated mood valence (Anderson, Anderson, & Deuser, 1996; Baron & Bell, 1975). Participants in a hot, versus thermoneutral, room reported decreased positive affect (Anderson, 1995). Participants in hot water tanks appear, and report themselves to be, irritable (Holland, Sayers, Keating, Davis, & Peswani, 1983). Heat exposure increased anxiety in rats (Mete, Kilic, Somay, & Yilmaz, 2012). In other work, participants completed office work type tasks in either a 22°C or 30°C room. Negative mood was higher in the hot room (Lan, Wargocki, Wyon, & Lian, 2011). Participants in a 33°C, versus 21°C, room were more likely to complete ambiguous story stems with negative emotion words (Rule, Taylor, & Dobbs, 1987).

Cold and Emotion Regulation

Cold is associated with decreased emotional valence (Cunningham, 1979; Keller et al., 2005; Sanders & Brizzolara, 1982; Shea, Slack, Keeton, Palinkas, & Leveton, 2011; cf. Tsutsui, 2012). Mood peaks around 70°C, with both colder and hotter temperatures being associated with decreased mood valence (Keller et al., 2005; Sundstrom & Sundstrom, 1986; see also d'Astous, 2000; Parsons & Conroy, 2006). Likewise, cold is associated with discomfort (Anderson, Anderson, Dorr, DeNeve, & Flanagan, 2000; Enander, 1987) and anxiety (Howarth & Hoffman, 1984). Many people experience negative mood states during the winter (Harmatz et al., 2000). People in colder countries show more negative moods and lower subjective well-being and life satisfaction (Maddison & Rehdanz, 2011; Rehdanz & Maddison, 2005). Evidence links extreme cold in the Arctic to depression, irritability, anger, anxiety, and negative mood (Cook, 1909; Enander, 1998; Guly, 2012; Gunderson, 1966; Haggarty et al., 2002; Palinkas et al., 2004; Palinkas & Suedfeld, 2008; Salam, 2012; Sandal, Leon, & Palinkas, 2006; Seale, Shellenberger, & Spence, 2008; Strange, & Youngman, 1971). Cold has been found to reduce dopamine synthesis (O'Brien, Mahoney et al. 2007), a physiological indicator of negative mood valence.

Findings on depression provide strong evidence linking cold to more negative mood. Depression often peaks in winter (Haggag, Eklund, Linaker, & Gotestam, 1990; Øyane, 2010; Øyane, Bjelland, Pallesen, Holsten, & Bjorvatn, 2008; Palinkas, Cravalho, & Browner, 1995; Schlager, Schwartz, & Bromet, 1993; Suhail & Cochrane, 1997), and more so to the extent of distance from the equator (Aschoff, 1981; Morken & Linaker, 2000). Reoccurring depression during the winter is a condition recognized as seasonal affective disorder (Dam, Jakobsen, & Mellerup, 1998; Kasper, Wehr, Bartko, Gaist, & Rosenthal, 1989; Lee, Gino, & Staats, 2012; Magnusson, 2000; Mersch, Middendorp, Bouhuys, Beersma, & Van Den Hoofdakker, 1999; Michalon, Eskes, & Mate-Kole, 1997; O'Brien, Sahakian, & Checkley, 1993; Oren & Rosenthal, 1992; Spoont, Depue, & Krauss, 1991; Rosenthal et al., 1984; Zuckerman, 1994). Winter seasonal affective disorder is more common in Italy than India, and Italy is colder than India (Tonettia, Sahub, & Natalea, 2002). Postpartum depression has been found to be greatest when it is cold (Sit, Seltman, & Wisner, 2011; Sylvén et al., 2008; cf. Jewell, Dunn, Bondy, & Leiferman, 2010).

Physiological Arousal

High arousal reduces non-dominant responses and perhaps self-control, given that self-control is less reflective of habitual and automatic tendencies. The lowest physiological arousal may occur around 22°C to 25°C (Bell & Green, 1982; Koots, Realo, & Allik, 2011; Scholander et al., 1950; Stewart, 2011; Van de Vliert, 2007). Researchers have implicated changes in arousal as a mediating mechanism of temperature influence (Clarke & Johnstone, 1999; Hancock & Vasmatzidis, 2003; Schmidt-Nielsen, 1991). Heat and cold increase physiological arousal, in that they can increase metabolism, adrenaline and noradrenaline, strain, discomfort, irritability, and frustration (al-Hadramy, 1988; Anderson et al., 2000; Cheuvront, Kenefick, Montain, & Sawka, 2010; Frank, Higgins, Fleisher, Sitzmann, Raff, & Breslow, 1997; Frese, 1987; Jezova et al., 1994; Scholander, Hock, Walters, Johnson, & Irving, 1950; Mawson, 1999; Simister, 2002; Sramek et al., 2000; Tavassoli, 2009; Van de Vliert, 2007). Heat has been found to increase heart rate (Anderson, 1995). Changes in arousal (systolic blood pressure), caused by heat (37°C versus 22°C), mediated increased cognitive task reaction time (in, Bell, Loomis, & Cervone, 1982). Findings on cold indicate that more stimulation is required to get the same stimulating effect (Panksepp, 1986), which implicates increased arousal (i.e., attenuated influence of incremental increases in arousal due to high levels of arousal).

Energy Provision

Self-control reductions occur via the depletion of metabolic substrate (Fairclough & Houston, 2004; Gailliot, 2008; Gailliot et al., 2007; Gailliot & Baumeister, 2007; Gailliot, Hildebrandt, Eckel, & Baumeister, 2010; Gailliot, Plant, Peruche, & Baumeister, 2009). The relationship between temperature and self-control may, therefore, pertain to changes in energy availability. One possible pattern is that heat and cold involve increased energy use and reduced availability.

Many researchers indicated that heat and cold deplete attention resources, thereby producing cognitive decrement (Bowen, 1968; Bursill, 1958, as cited in Bell & Greene, 1982; Davis, Baddeley, & Hancock, 1975; Kahneman, 1973; Provins & Bell, 1970; Schneider & Shiffrin, 1977; Teichner, 1958; Vaughan, 1977; Wickens, 1980; for a review see, Hancock & Vasmatzidis, 2003). Increased energy use in the heat is indicated by increases in metabolic and heart rates, brain activity and oxygen use, and oxygen uptake, as well as deepened respiration (Anderson, 1989, 1995; Bell, 1981; Furtado et al., 2007; Hocking, Silberstein, Lau, Stough, & Roberts, 2001; Nybo & Secher, 2004; Rotton, 1985; Rotton, Shats, & Standers, 1990; Scholander, Hock, Walters, Johnson, & Irving, 1950). Performance of cognitive tasks in the heat (35°C versus 25°C) is associated with increased frontal lobe brain activity (Hocking et al., 2000). One study found that cold increased oxygen consumption (Armstrong & Thomas, 1990).

Cold (-5°C versus 24°C) is associated with reduced plasma volume (Cornachione, 2011), of metabolite substrate. Cold and heat have been found to reduce blood flow to the brain (Ehrmantraut, Ticktin, & Fazekas, 1957; González-Alonso, 2007; Hoffman, 2001; Nybo, Møller, Volianitis, Nielsen, & Secher, 2002; Nybo & Nielsen, 2001; Nybo, Nielsen, Møller, Pedersen, & Secher, 2002; Nybo, 2008; Nybo & Secher, 2004; Schmoker et al., 2009). Among marathon runners, heat has been found to reduce delivery of oxygen to the brain (González-Alonso, 2007). Reduced blood flow to the brain reduces physical persistence, and motivation may overcome this effect (Nybo, Nielsen, Blomstrand, Møller, & Secher, 2003). Decreases in cerebral blood flow and velocity have been noted (Anzi, Turner, Gibson, & Neely, 1978; Nybo & Nielsen, 2001a,b). One study found that heat (40°C versus 18°C) reduced oxygen content in the prefrontal cortex, which was associated with exhaustion during cycling and perhaps mental fatigue (Périard, Thompson, Caillaud, & Quaresima, 2012). Consistent with this body of evidence, neurotransmitter depletion and reduced activity occurred with heat and cold (O'Brien et al., 2007; Mahoney et al., 2007; Shurtleff, Thomas, & Ahlers, 1992), findings that may explain influence of temperature on cognition (Nybo & Secher, 2004; O'Brien et al., 2007; Shurtleff et al., 1993). Heat may also deplete brain glycogen (Gailliot, 2008).

Hypoglycemia is linked to both hypothermia and hyperthermia (Bichel, Canivet, Damas, & Lamy, 1994; Field, 1989; Freinkel, Boyd, Harris, Robinson, & Mager 1972). Heat is known to produce many of the same symptoms caused by hypoglycemia (loss of coordination, confusion, delirium, convulsions, seizures, fainting, loss of consciousness, coma, and death; Fuller, Carter, & Mitchell, 1998; Schlader, Stannard, & Mundel, 2010; Walters, Ryan, Tate, & Mason, 2000; Wetsel, 2011). Heat was associated with increased hospital admissions for diabetic symptoms (Green, Basu, Malig, Broadwin, Kim, & Ostro, 2010; Semenza, McCullough, Flanders, McGeehin, & Lumpkin, 1999) and Winter with worsened glycemic control among people who experienced Diabetes (Tseng et al., 2005).

Ingesting glucose attenuates some of the effects of heat, namely increased aggression (Baron & Bell, 1976), decreased physical activity (Pitsiladis & Maughan, 1999; for findings on both heat and cold, see Talbott, 1935), and reduced working memory (Bandelow, 2010). In rats, a glucose injection reduced amnesia caused by hypothermia (Flint & Riccio, 1996).

Discussion

Research across a variety of domained links both heat and cold to signs of reduced self-control. Some inconsistencies exist, but a general pattern was supported. Temperature may relate to other findings pertaining to self-control that are not included in this review (see Ardnt, Greenberg, Solomon, Pyszczynski, & Linda, 1997; Cao & Wei, 2005; Gailliot, Schmeichel, & Baumeister, 2006). Self-control is reduced by prior use (Baumeister & Muraven, 2000). Temperature effects may be especially likely to emerge, therefore, after high self-control demand.

A few ideas for future exploration emerge. Environment consistent effects, such as those found for memory (Godden & Baddeley, 1975), may occur. Intentions, thoughts, and tendencies that occur or develop at a particular temperature may be likely to emerge at similar temperatures. The hypothalamus likely is important in the link between temperature and self-control, provided its role in metabolism, aggression, sex, and internal and external thermoregulation. Global warming pertains to a breadth of human activity. It may also influence self-control.

Norms and values may reflect the influence of temperature on self-control. They may, for example, counter the influence of temperature, or be in condonation of its influence. The Southern United States is hot, and Southern values manifest support for defense of honor (Nisbett & Cohen, 1996). The Day of the Dead is prominent in Mexico, which may bolster coping with thoughts of death activated by heat. Norms and values embracive of alcohol consumption on Independence Day in the United States and MidSummer Day in Finland may reflect the influence of heat. Humanity has desert origins, and so physiology may more adequately respond to heat than cold (Anderson 1989; Department of the Army, 2005; Nikolopoulou & Lykoudis 2006; Vanos et al., 2012). Technological advances that effectively minimize heat may be the way of the future – large scale outdoor air conditioning, for example, could provide vast benefits.

This review focused on temperature. Other weather variables may be relevant, such as those related to comfort, including wind, humidity, and direct sunlight. The effect of heat, for example, may be negated by a nice breeze on a cloudy day.

Away from middle temperatures, at hypothermic and hyperthermic states, people die. Along the spectrum toward death, it makes sense that psychological processes fail. Psychological capacities to appear later ontogenetically compromise sooner upon physiological demand. Thus, it is logical to conclude that self-control is sensitive to temperature. This review shows that, at high and low temperatures experienced commonly, self-control may have been commonly reduced.

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