Bored Into Depletion? Toward a Tentative Integration of Perceived Self-Control Exertion and Boredom as Guiding Signals for Goal-Directed Behavior

Wanja Wolff[1,2] and Corinna S. Martarelli[3]

[1]Department of Sport Science, University of Konstanz; [2]Department of Educational Psychology, University of Bern; and [3]Faculty of Psychology, Swiss Distance University Institute

Abstract

During the past two decades, self-control research has been dominated by the strength model of self-control, which is built on the premise that the capacity for self-control is a limited global resource that can become temporarily depleted, resulting in a state called ego depletion. The foundations of ego depletion have recently been questioned. Thus, although self-control is among the most researched psychological concepts with high societal relevance, an inconsistent body of literature limits our understanding of how self-control operates. Here, we propose that the inconsistencies are partly due to a confound that has unknowingly and systematically been introduced into the ego-depletion research: boredom. We propose that boredom might affect results of self-control research by placing an unwanted demand on self-control and signaling that one should explore behavioral alternatives. To account for boredom in self-controlled behavior, we provide a working model that integrates evidence from reward-based models of self-control and recent theorizing on boredom to explain the effects of both self-control exertion and boredom on subsequent self-control performance. We propose that task-induced boredom should be systematically monitored in self-control research to assess the validity of the ego-depletion effect.

Keywords

self-control, ego depletion, boredom, value-based models, psychoneurophysiological approach

Self-control is a crucially important human capacity. Self-control facilitates goal achievement by volitionally directing attention toward goal-directed behavior (de Ridder, Lensvelt-Mulders, Finkenauer, Stok, & Baumeister, 2012). That self-control is among the most researched psychological concepts is a testament to its societal relevance (Duckworth, 2011). In everyday life, people face many self-control challenges, and how effectively they deal with those challenges greatly affects success in diverse parts of their life. For example, in a 32-year longitudinal study, Moffitt et al. (2011) showed that "childhood self-control predicts physical health, substance dependence, personal finances, and criminal offending outcomes" (p. 2693).

Despite good intentions, self-control does not always work (Hagger, Wood, Stiff, & Chatzisarantis, 2010), and applying self-control is generally perceived as effortful and aversive (Wolff, Sieber, Bieleke, & Englert, 2019). A multitude of theoretical accounts as to why and when self-control fails to work have been proposed and tested (e.g., Beedie & Lane, 2012; Inzlicht, Schmeichel, & Macrae, 2014; Kotabe & Hofmann, 2015). By far the most popular theoretical account on self-control is the strength model of self-control (Baumeister, Bratslavsky, Muraven, & Tice, 1998; Baumeister, Tice, & Vohs, 2018; Baumeister, Vohs, & Tice, 2007). The strength model states that self-control relies on a limited metabolic

Corresponding Author:
Wanja Wolff, University of Konstanz, Universitätsstrasse 10, 78464 Konstanz, Germany
E-mail: wanja.wolff@uni-konstanz.de

resource that can become temporarily depleted by prior exertion of self-control (Baumeister et al., 2007). This supposedly leads to a state called ego depletion, in which subsequent acts that place demands on self-control are performed less effectively (Baumeister et al., 1998). A substantial body of evidence supports the ego-depletion concept (Cunningham & Baumeister, 2016). On the behavioral level, a multitude of studies have shown that ego depletion leads to impaired performance on a broad range of subsequent tasks that place demands on self-control (for meta-analyses, see Giboin & Wolff, 2019; Hagger et al., 2010). On the experiential level, applying self-control leads to perceptions of exertion (Milyavskaya, Inzlicht, Johnson, & Larson, 2019; Wolff et al., 2019), thereby attesting to the implied costliness of exerting self-control (Baumeister et al., 1998). However, large-scale preregistered replication failures (Hagger et al., 2016; Koppel, Andersson, Västfjäll, & Tinghög, 2019), evidence of publication bias (Carter & McCullough, 2014; Wolff, Baumann, & Englert, 2018), and critiques regarding the models' mechanistic underpinning (Beedie & Lane, 2012; Inzlicht et al., 2014; Kurzban, Duckworth, Kable, & Myers, 2013) have called its main premise (i.e., the ego-depletion effect) into question.

Taken together, self-control is among the most researched psychological concepts (Duckworth, 2011), which is of great societal relevance (Moffitt et al., 2011), but an inconsistent body of literature limits our understanding of how self-control operates. In the first part of this article we discuss boredom as one potential confound that might have contributed to the heterogeneous findings in ego-depletion research. Notable recent exceptions notwithstanding (e.g., Milyavskaya et al., 2019), the postulated role of boredom in ego-depletion research has been largely overlooked so far. In the second part of this article we propose that integrating conceptualizations of self-control allocation as a reward-based choice (e.g., Berkman, Hutcherson, Livingston, Kahn, & Inzlicht, 2017; Kool & Botvinick, 2014; Kurzban et al., 2013; Shenhav, Botvinick, & Cohen, 2013) and current theorizing on boredom (Westgate & Wilson, 2018) can contribute to a better understanding of how people choose to allocate effort and engage in goal-directed behavior (Cohen, McClure, & Yu, 2007; Mansouri, Koechlin, Rosa, & Buckley, 2017).

Bored Into Depletion?

To most, boredom is a ubiquitous experience (Harris, 2000), but until recently it has received surprisingly little attention as a research topic (Bench & Lench, 2013; Gomez-Ramirez & Costa, 2017; Westgate & Wilson, 2018). This has prompted researchers to emphasize the need for more research on this topic (Mills & Christoff,

2018), and there has been increased interest in boredom (van Tilburg & Igou, 2017). Although researchers initially ascribed relatively little functional relevance to boredom for the understanding of human behavior, this view has also changed (Gomez-Ramirez & Costa, 2017; Westgate & Wilson, 2018). Indeed, boredom has been identified as an influential motivator for negative and positive behaviors alike (Westgate & Wilson, 2018). Boredom is related to a host of negative outcomes, such as gambling behavior (Goldstein, Vilhena-Churchill, Stewart, Hoaken, & Flett, 2016), poor mental health (Binnema, 2004), violent offenses (Dåderman & Lidberg, 1999), and even youth suicide (Heled & Read, 2005). However, boredom also appears to facilitate creativity (Harris, 2000) and prosocial intentions (van Tilburg & Igou, 2017). More generally, it has been proposed that boredom is neither good nor bad per se but rather assumes a key role in indicating that a change of behavior is required (Danckert, 2019; Westgate & Wilson, 2018).

When do we get bored?

Imagine being a university student and, to receive course credit, you have to take part in an experiment in which your task is simply to transcribe a text for an uncertain amount of time. In this situation you are likely to get bored. According to the meaning-and-attention-components (MAC) model, boredom arises when one feels unable to successfully engage attention in an activity and/or when the current activity is perceived as low in meaning (Westgate & Wilson, 2018). Both attentional failure (i.e., incongruence of cognitive demands and mental resources; Wickens, 2002) and lack of meaning (i.e., incongruence of current activities and one's own goals) are thought to independently contribute to the sensation of boredom (Westgate & Wilson, 2018). Attentional boredom occurs when task-induced attentional demands are too low (understimulation) or too high (overstimulation). This implies that boredom occurs as a result not only of too few demands (e.g., while transcribing a text from a computer screen) but also of too many (e.g., while trying to solve anagrams without knowing that they are unsolvable). Indeed, if one conceives boredom as a functional signal that computational capabilities should be oriented somewhere else (Gomez-Ramirez & Costa, 2017), this makes sense: If a task is too hard to make its pursuit worthwhile, deploying attentional capabilities toward this activity is a nonfunctional course of action. The MAC model also proposes mixed states of boredom that occur when people fail to successfully engage attention in an activity that is also perceived as meaningless. It is likely that many experimental tasks (willingly or

unwillingly) invoke some form of mixed boredom. Finally, state boredom is not static, and the boredom one experiences at any given time is likely to vary both in intensity (Mills & Christoff, 2018) and in type (Westgate & Wilson, 2018).

How can boredom account for (some) inconsistencies in the ego-depletion literature?

We propose that the causes of state boredom (i.e., attentional failure and/or lack of meaning) and its functional role (i.e., signaling that one should change activity), as conceptualized by the MAC model, make it very likely that boredom might have unwillingly been introduced as a confound in ego-depletion research. Specifically, we suggest that the experimental approach that has traditionally been used to investigate ego depletion is prone to inducing forms of boredom as specified in the MAC model, thereby altering behavior and affecting performance on subsequent tasks that place demands on self-control.

The ego-depletion effect is traditionally induced with the sequential-task paradigm, which is used in the experimental group to assess how performing a primary self-control task affects the performance of a subsequent secondary self-control task (Hagger et al., 2016). In general, completing high self-control tasks (HCTs) is demanding (e.g., rapidly transcribing a text while omitting each instance of the letter *e*; Wolff et al., 2018). In contrast, the control group performs a primary task that supposedly does not rely on self-control (or places substantially less demand on self-control than the HCT). This low-control task (LCT) is usually very simple (e.g., merely transcribing a text).

Central to the tasks that are frequently used in ego-depletion research is the requirement for varying levels of attentional control that are needed to effectively complete the task (i.e., more control is needed in an HCT than in an LCT). From an ego-depletion point of view, this makes sense because, as Schmeichel and Baumeister (2010) proposed, "attention control is the single most important or influential form of self-control" (p. 31). Thus, the more attentional control a task demands, the more self-control is required to complete the task. To ensure that participants in the control group are not depleted as well, an LCT should then place as little demand on attention as possible.

However, according to the MAC model, boredom occurs because a task places attentional demands that are either too high or too low (Eastwood, Frischen, Fenske, & Smilek, 2012; Westgate & Wilson, 2018). Thus, although it places little demand on self-control, an LCT could conceivably cause higher levels of boredom than an HCT as a result of understimulation. Although there are more than 600 studies on ego

depletion (Cunningham & Baumeister, 2016), we know of only one study that directly tested this possibility (Bieleke, Barton, & Wolff, 2020). Supporting the ideas presented here, Bieleke et al. (2020) observed that a traditional Stroop task (i.e., with congruent and incongruent blocks) was perceived as being more boring than the more demanding modified Stroop task (i.e., with interspersed task-switching blocks). Note that we are not the first to suggest that boredom might have confounded results in ego-depletion research (e.g., Francis, Milyavskaya, Lin, & Inzlicht, 2018; Job, Dweck, & Walton, 2010; Milyavskaya et al., 2019). Other researchers have also interpreted inconsistent findings in terms of boredom. For example, Job et al. (2010) found that in one experimental condition, instead of performing worse, participants performed better after an HCT than after an LCT (Study 2). In their discussion, Job et al. suggested that boredom in the LCT might have led to these surprising findings. However, they did not test the hypothesis further. The strongest evidence regarding a potential overlap between boredom and LCTs is probably more indirect: Tasks that have been used in ego-depletion research (e.g., Stroop task, transcription task, *N*-back task; Wolff et al., 2018) are sometimes also used as experimental inductions of boredom (Atchley, Klee, & Oken, 2017; London, Schubert, & Washburn, 1972; Markey, Chin, Vanepps, & Loewenstein, 2014).

We believe that boredom-induced inconsistencies in ego-depletion research largely stem from understimulation in the LCT compared with the HCT. However, following from the MAC model, it is also likely that overstimulation might have acted as a confounding factor. For example, the time spent trying to solve anagrams (which, unbeknownst to the participants, are in fact unsolvable) has been used as a measure of currently available self-control strength (i.e., as an indicator of ego depletion; Baumeister et al., 1998). In addition to placing high demands on self-control, working on such a task might also induce boredom as a result of overstimulation because the cognitive demands (i.e., complicated anagrams) appear to exceed one's mental resources (i.e., the skills to solve the anagrams). Although we are not aware of any research that has directly tested this possibility, we would argue that overstimulation in HCTs is likely to be less prevalent than understimulation in LCTs: Although HCTs tend to be perceived as more difficult (Hagger et al., 2016), there appears to be no consistent ceiling effect in the task-difficulty ratings of HCTs (Milyavskaya et al., 2019; Wolff et al., 2019), and performance on an HCT can quickly improve over time, suggesting that participants get better at the task (Wolff et al., 2019).

To arrive at tasks that differ only in regard to the self-control demands they impose, researchers often

use LCTs and HCTs that are structurally very similar—for example, as noted above, merely transcribing a text (LCT) compared with transcribing the same text while omitting any instance of the letter *e* (HCT). Thus, in regard to the meaning component of boredom, it is conceivable that HCTs and LCTs tend to be perceived similarly. However, although we expect differential effects of perceived meaning to play only a minor role in LCTs and HCTs, it is very likely that individual differences affect the meaning one ascribes to a self-control task and consequently the boredom one experiences while performing the task. For example, when participants were asked to perform a self-control task that was more congruent with their own interests, depletion effects tended to be smaller (for a meta-analysis, see Giboin & Wolff, 2019). However, it is important to note that the interpretation of these findings in terms of boredom is speculative, and we are not aware of any research that has tested the role of meaningless boredom in ego-depletion research.

Finally, and to complicate matters further, task characteristics can change as a function of time, which might alter sensations of boredom, perceived self-control costs, and how the latter is required in dealing with the former: A task that was initially challenging (or overchallenging) might become easy after prolonged execution. This point is important because although an easier task might place little demand on self-control than a harder task, boredom is thought to signal that one should allocate one's attention somewhere else (Danckert, 2019; Westgate & Wilson, 2018). This might lead to the paradoxical effect that self-control is needed to keep attention on track in a task that was originally designed to place little to no demand on self-control. Indeed, in a study by Milyavskaya et al. (2019), participants reported elevated levels of effort and fatigue in a boring task that simply required passive number viewing.

Taken together, sensations of boredom might affect the results of research on self-control by placing an unwanted demand on self-control and signaling that one should explore behavioral alternatives. This confound probably primarily manifests itself as understimulation in LCTs, thereby contributing to replication failures in ego-depletion research (for a similar argument, see Milyavskaya et al., 2019). However, boredom resulting from overstimulation and boredom resulting from a lack of meaning could both also have altered outcomes of ego-depletion studies. For example, if, in addition to placing demands on self-control, an HCT were perceived to be meaningless, this might result in an inflated effect size of the observed ego-depletion effect. As long as this potential confound of boredom in ego-depletion research has not been systematically assessed, it is impossible to truly evaluate the merit of

the strength model of self-control. In addition, because of its reliance on a metabolic self-control resource, the strength model of self-control appears ill-suited to conceptually incorporate the functional role of boredom for performance in tasks that place demands on self-control. We propose that propositions from the MAC model of boredom and from recent reward-based conceptualizations of self-control can be integrated to specify how both concepts affect goal-directed behavior.

Toward a Tentative Integration of Perceived Self-Control Exertion and Boredom as Guiding Signals for Goal-Directed Behavior

Adaptive behavior relies on a continuous cost–benefit analysis that weighs the merits of continuing with a course of action against switching to an alternative activity (Mansouri et al., 2017). This cost–benefit analysis essentially assesses whether the brain's computational capabilities are being put to adequate use. We suggest that the sensation of applying self-control (i.e., perceived exertion) and the experience of boredom contribute distinctively to the outcome of this cost–benefit analysis and thereby to the resultant behavior (for our proposed working model, see Fig. 1).

We suggest that, consistent with previous research (e.g., Inzlicht et al., 2014), perceived exertion primarily reduces the willingness to exert further effort. More precisely, this effort avoidance is driven by the outcome of a continuous comparison between the value that is expected from exerting control against its costs, which scale as a function of the duration for which control is applied (Kurzban et al., 2013). We suggest that, in line with recent work (Danckert, 2019; Westgate & Wilson, 2018), the sensation of boredom primarily instigates behavioral change. More accurately, this impulse to search for alternative activities stems from discounting the value of a current activity (Berlyne, 1970) and an increased sensitivity to future rewards (Milyavskaya et al., 2019). We suggest that within the course of goal-directed behavior, self-control costs and boredom have unique functions—the former triggering effort avoidance and the latter triggering behavioral change (this triggering function of self-control costs and boredom is expressed in Fig. 1 by the terms "avoid effort" and "change behavior," respectively).

To elaborate on these propositions, we first briefly summarize theoretical accounts and empirical support for the notion that self-control is indeed costly and that exerting control skews the underlying cost–benefit analysis toward effort aversion. Second, we summarize recent computational and empirical evidence supporting the proposition that boredom indeed signals the
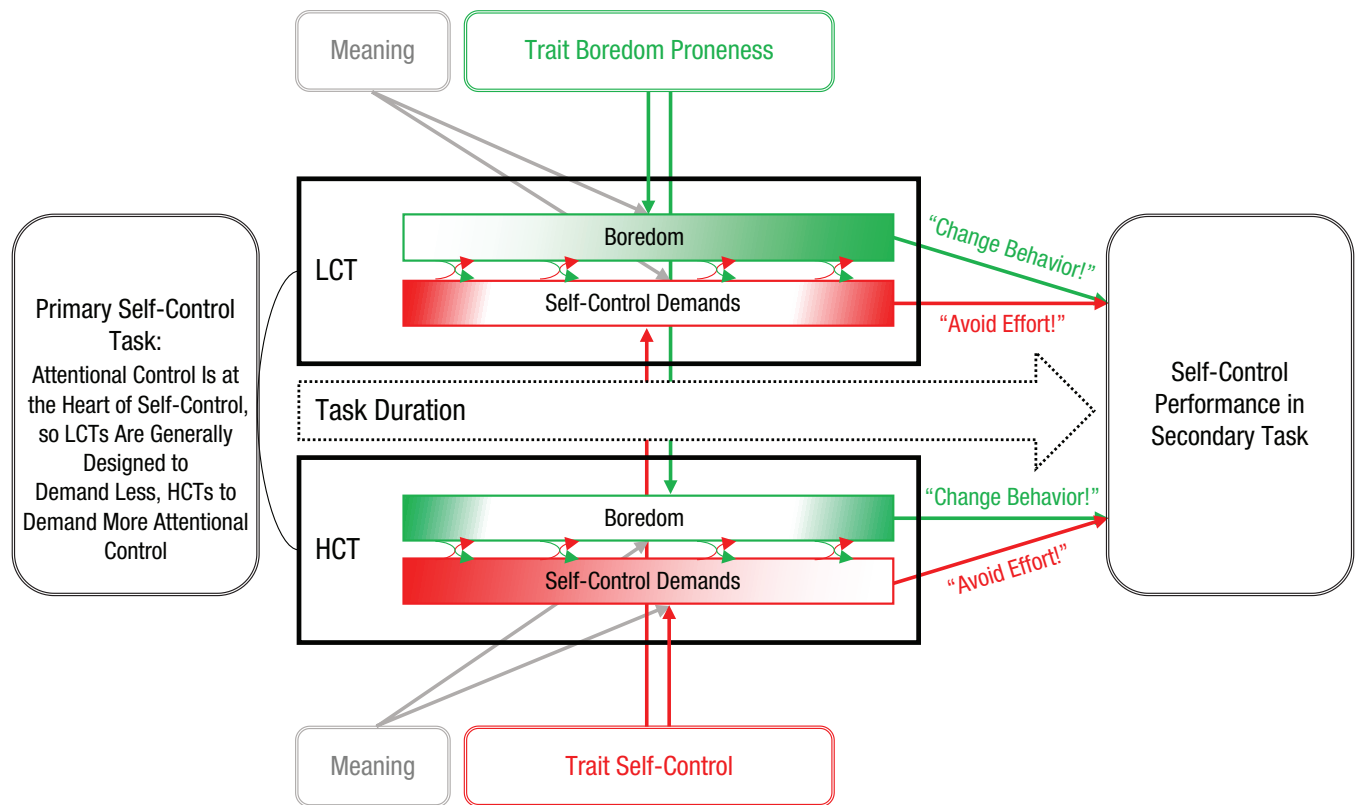
Fig. 1. Working model of the potential interplay between boredom and self-control within the context of a traditional ego-depletion study. Primary tasks are designed to be either low-control tasks (LCTs) or high-control tasks (HCTs). For example, the congruent Stroop is frequently used as an LCT, and the incongruent Stroop is frequently used as an HCT (Wolff, Baumann, & Englert, 2018). In the published literature, the duration of the primary task (horizontal arrow in the middle) varies greatly among studies (Giboin & Wolff, 2019). For example, the primary task might consist of 50 Stroop trials (e.g., Job, Dweck, & Walton, 2010) or 300 Stroop trials (e.g., Govorun & Payne, 2006). The model proposes that task characteristics change as function of task duration and that this in turn leads to changes in task-imposed self-control demands and task-induced boredom. The red rectangles depict self-control demands, and the green rectangles depict task-induced boredom. The gradient highlights increasing/decreasing self-control demands or task-induced boredom. We propose that understimulation in LCTs leads to increases in the self-control that is needed to keep attention on track while working on a boring task. On the other hand, HCTs might be boring at the beginning because of overstimulation and at the end because of understimulation. The figure is schematic and meant to illustrate dynamic changes in task-imposed self-control and task-induced boredom as a function of task duration. We suggest that these changes distinctively contribute to the outcome behavior. This contribution is illustrated by the paths that connect boredom and self-control demands with subsequent self-control performance. In terms of a cost–benefit analysis, boredom signals whether one should seek out a more rewarding behavioral alternative ("change behavior"), and the perceived costs of self-control signal whether one should avoid investing further effort ("avoid effort"). Whether or not an ego-depletion effect is observed should then depend on the separate and multiplicative effects of both pathways on performance in the secondary task. For example, an increase in boredom is expected to instigate behavioral change but also increase the self-control demands that are required to keep attention on track. Both components of the meaning-and-attention-components model (Westgate & Wilson, 2018) are integrated in the proposed working model: Depending on the meaning that one attributes to the task, the experience of boredom and the allocation of self-control can vary. Finally, the ego-depletion effect is likely moderated by individual differences. We propose that trait self-control and boredom proneness are likely to moderate the ego-depletion effect.

need for behavioral change. Finally, we briefly summarize the neuroscientific understanding of how control operates and highlight similarities to findings in the emerging literature on the neuronal correlates of boredom.

Costs of self-control and effort avoidance

The application of self-control is perceived as costly, and perceived costs of control scale with the duration of control allocation (Kurzban et al., 2013; Wolff et al.,

2019). For example, a recent high-powered study showed that performing a Stroop task led to sensations of tiredness that increased as a function of task duration (Wolff et al., 2019). It is important to note that these perceived costs of control do not necessarily represent structural limitations of the brain (e.g., a limited metabolic self-control resource; Baumeister et al., 2007) but might result from functional constraints of the processing system itself (Shenhav et al., 2017).[1] Circumventing the notion of intrinsic costs of control altogether, it has been proposed that the costs of control are opportunity

costs (Kurzban et al., 2013). Thus, while exerting control in one activity, one has to forego other opportunities with potential value. Regardless of whether the application of control is costly because of functional-processing constraints or opportunity costs (or a combination of both), it has been suggested that the resultant perceived exertion serves as a signal that indexes these costs (Kurzban et al., 2013; Shenhav et al., 2017). Supporting this suggestion is research showing that applying constant levels of effort toward a task that puts high demands on self-control for a prolonged period of time leads to an increase in perceived exertion, whereas task performance might not deteriorate or even improve (Wolff et al., 2019). This indicates that perceived exertion reflects not the depletion of self-control resources (which should result in performance impairment) but rather the rising intrinsic and/or opportunity costs of control. This disconnect between perceived exertion and actual performance has been observed not only in ego-depletion research (Francis et al., 2018; Wolff et al., 2019) but also in related neurological research on fatigue (DeLuca, 2005). In line with the above findings, research in this field has suggested that perceptions of fatigue do not directly map onto fatigued resources (Sandry, Genova, Dobryakova, DeLuca, & Wylie, 2014).

Recent theorizing and empirical evidence on self-control both seem to support the idea that the allocation of self-control is effortful and that the sensation of control-induced exertion has the function of tracking the costs of one's current activity. These costs of exerting self-control in turn reduce the motivation to further exert self-control (Inzlicht & Schmeichel, 2012). Effort avoidance has empirically been reflected, for example, in a reduced willingness to engage in tasks that are effortful (Sjåstad & Baumeister, 2018) or in a reduction of effort that is invested in activities that place demands on self-control (e.g., Lin, Saunders, Friese, Evans, & Inzlicht, 2020). It is important to note that some findings suggest that rather than causing effort avoidance, exerting self-control might increase approach motivation (Schmeichel, Harmon-Jones, & Harmon-Jones, 2010) and reward sensitivity (Wagner, Altman, Boswell, Kelly, & Heatherton, 2013). At first, these findings may appear to be at odds with the ideas presented here and more closely linked to the function we suggest for boredom in the current framework (see Fig. 1). However, more recent studies that followed up on these findings indicate that exerting self-control appears to reduce the motivation to control approach motivation rather than increasing the approach motivation (e.g., Haynes, Kemps, & Moffitt, 2016). Further, prior exertion of self-control led only to increased approach behaviors when the required effort for approaching rewards was low

(Giacomantonio, Jordan, Fennis, & Panno, 2014). If the required effort was high, then prior exertion of self-control even reduced approach behavior. This is in line with the ideas we put forward in the current article. If the to-be-approached activities are intrinsically rewarding (e.g., delicious candy) but one has already exerted control in a previous HCT, then approach behavior is expected only when the new task itself does not require (much) effort.

Although exerting self-control is aversive and its application leads to the avoidance of further effort, self-control is also highly functional and facilitates goal attainment (de Ridder et al., 2012; Moffitt et al., 2011). Accordingly, more recent theoretical accounts have conceptualized the allocation of self-control as a reward-based choice (Berkman et al., 2017), in which an agent weighs the benefits of pursuing a current course of action against the costs that increase over time. For example, it has been suggested that the choice to apply control is driven by a utility-maximization approach, as specified by labor-supply theory (Kool & Botvinick, 2014); by the computation of opportunity costs (Kurzban et al., 2013); or by a maximization of the expected value of control (Shenhav et al., 2013). What each of these approaches has in common is that self-control is applied only if it is subjectively worth it. In turn, exertion-induced effort avoidance can be overcome by increasing the value of an activity. This is in line with research showing that incentives can offset ego-depletion effects (Muraven & Slessareva, 2003).

Boredom as a functional signal for exploring behavioral alternatives

Whereas applying self-control produces costs that serve as an adaptive signal (e.g., "should I continue to put effort into this Stroop task?"), boredom appears to track the diminishing value of an activity, thereby serving as a prompt for exploring more interesting or enjoyable alternatives (e.g., "transcribing this text is boring; I would like to change activities"; Westgate & Wilson, 2018). Note that what is deemed rewarding is likely to depend on the situation in which one finds oneself: In addition to instigating a shift to more pleasurable behavioral alternatives, boredom might sometimes even prompt a shift toward hedonically negative experiences (Bench & Lench, 2019). It has been suggested that whether boredom causes people to seek positive or negative experiences depends on the type of experience that has led to boredom. Specifically, getting bored during a hedonically negative activity should instigate the search for hedonically positive experiences and vice versa. Given that ego-depletion tasks tend to be perceived as somewhat aversive (e.g., Hagger et al., 2016;

Wolff et al., 2019), boredom during ego depletion might primarily instigate behavioral change toward hedonically positive experiences (e.g., delicious candy).

The conceptualization of boredom as an adaptive signal that shifts one's resources to seek out a more rewarding experience has been supported by recent computational (Gomez-Ramirez & Costa, 2017) and experimental (Geana, Wilson, Daw, & Cohen, 2016) work. Cognitive neuroscience conceptualizes the brain as Bayesian, trying to minimize surprise by constantly integrating sensory information to update its estimate of the current state of the world. However, it has been argued that this model does not suffice in explaining decisions under uncertain conditions or, more generally, in explaining exploration behavior (e.g., stop trying to solve unsolvable anagrams and engage attention in alternative activities). To address this shortcoming, Gomez-Ramirez and Costa (2017) proposed a mathematical model that ascribes a key role to boredom as a signal to discount current rewards and trigger a change in behavior (Gomez-Ramirez & Costa, 2017). Geana et al. (2016) tested these predictions empirically in a series of experiments: They manipulated the amount of information in a computer game to cause either understimulation or overstimulation. Both understimulation and overstimulation (albeit to a lesser extent) caused boredom and triggered exploration behavior (switching to another task) compared with a condition in which no boredom was induced because attentional demands and mental resources were matched. Most importantly, exploration behavior was positively correlated with the subjective experience of boredom as well as with the value of other future options (future reward). A more dramatic example attesting to the aversive nature of boredom that in turn instigates behavioral change comes from research showing that some people choose to administer electric shocks to themselves rather than doing nothing (Wilson et al., 2014).

These theoretical, computational, and behavioral approaches have been accompanied by research on the mechanisms by which boredom triggers behavioral change. For example, research indicates that the sensation of boredom leads to a discounting of an activity's current value (Berlyne, 1970) and increases approach motivation (Moynihan et al., 2015). Further, recent neuroscientific work showed that after a boring task participants displayed a larger feedback negativity, which has been interpreted as a neural index for reward sensitivity (Milyavskaya et al., 2019). Milyavskaya et al. found no evidence for a change in reward sensitivity in participants that had performed a self-control-demanding task instead, which is in line with our current proposal.

To sum up, we propose that the effortful sensation that accompanies the application of self-control and the sensation of boredom have distinct functions in the cost–benefit analysis that drives goal-directed behavior. By triggering effort avoidance, exerting self-control primarily affects the cost side of this analysis. In contrast, by instigating behavioral change, boredom primarily affects the benefit side. In regard to ego depletion, this implies that performance in the secondary task should hinge on the combined effects of the self-control demands and boringness of the primary task. As costs and benefits combine to guide behavior, we propose that boredom and control exertion interact in how they affect future behavior. In regard to ego-depletion research, this is likely to affect performance on the secondary task in intricate ways. For example, by causing a devaluation of an activity, boredom also reduces the cost one can justifiably incur in this activity. In addition, boredom increases sensitivity to more rewarding alternatives, thereby increasing the effort (i.e., cost) that is needed to stay engaged in the current activity. Because task-induced boredom and self-control demands dynamically change over time (e.g., as a result of learning or habituation), the influence both signals have on performance should also vary as a function of task duration in an ego-depletion task. To further advance research on the ego-depletion effect, it is therefore crucial to track boredom and self-control costs with high temporal resolution during the primary and secondary tasks.

Similarities and dissimilarities in the neuroscience of self-control and boredom

A substantial body of research has investigated the neural correlates and mechanistic underpinnings of self-control (Heatherton, 2011; Shenhav et al., 2017; Turner et al., 2019). In a nutshell, control processes are primarily orchestrated by structures in the executive network—the dorsal anterior cingulate cortex (dACC) and the lateral prefrontal cortex (lPFC; Shenhav et al., 2013; Turner et al., 2019). Specifically, research indicates that the dACC calculates the value of applying control by integrating "information about rewards and costs that can be expected in a control-demanding task" (Shenhav et al., 2013, p. 217). Information on potential rewards is received primarily from the ventromedial prefrontal cortex (vmPFC), which provides information on the current action's value relative to alternative actions (Berkman, 2017; Gläscher, Hampton, & O'Doherty, 2009; Mansouri et al., 2017; Strait, Blanchard, & Hayden, 2014). Further, the dACC specifies the control command (identity and intensity), and the actual top-down control is then governed by structures in the lPFC. The

dACC monitors the control process (on the afferent side) and adjusts it (on the efferent side) if necessary. The effortful/costly part of control is then executed by the lPFC. To summarize, the dACC and the lPFC (among others) differentially contribute to the specification, regulation, and monitoring of control processes (for a comprehensive review of dACC function in regard to self-control as a reward-based choice, see Shenhav et al., 2013, 2017).

So far, only a few studies have investigated the neuronal underpinnings of boredom (Mills & Christoff, 2018). The default-mode network in particular has been implicated in boredom (Danckert & Merrifield, 2018). The association of boredom with the default-mode network appears to be quite intuitive, given that activation in the default-mode network has been found across many studies—studies that did not directly investigate boredom—when people are not attentionally engaged in a primary task (e.g., Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Mason et al., 2007). Within the default-mode network, the association of the vmPFC with boredom is of particular interest for the current proposal (Mathiak, Klasen, Zvyagintsev, Weber, & Mathiak, 2013). Research indicates that the vmPFC integrates competing value signals (Strait et al., 2014), encodes expectations about future rewards (Gläscher et al., 2009), and thereby assumes a key role in signaling whether a change in behavior is needed (Domenech & Koechlin, 2015). It should be noted that vmPFC activity also appears to be highly relevant for self-control (Berkman, 2017) because the dACC monitors information from the vmPFC to adjust the control command if necessary (Shenhav et al., 2013). The joint importance of the vmPFC for boredom and self-control and its link to the dACC might point toward a tentative mechanistic path on how boredom can affect self-control demands in an LCT. In the context of the framework we present here, this indicates how boredom-induced changes in valuation might affect how much effort one can justifiably put into a task.

Some studies have also reported boredom-induced activations in structures of the executive network. However, these findings are somewhat inconsistent. For example, in one study, the lPFC was implicated in boredom (Dal Mas & Wittmann, 2017), whereas other studies did not find this implication (e.g., Danckert & Merrifield, 2018). Further, some studies showed that boredom was associated with activation in the cingulate cortex (Dal Mas & Wittmann, 2017; Danckert & Merrifield, 2018). As outlined above, these areas also play an important role in self-control. It is possible that some of the inconsistencies in regard to the involvement of the executive network in boredom stem from between-studies variation. Specifically, differences in regard to

whether boredom manipulations require some form of sustained attention (i.e., self-control) might affect the involvement of structures in the executive network. Thus, some boredom manipulations might also impose self-control demands (possibly because of the effort needed to stay attentionally engaged when the task is very boring). Indeed, in a study in which the boredom manipulation required simple but frequent yes/no responses toward stimuli, higher activations in the lPFC were observed (Dal Mas & Wittmann, 2017). No such activation was found when the boredom manipulation consisted of passive video watching (Danckert & Merrifield, 2018). The differential recruitment of structures in the executive-control network in different boredom inductions can cautiously be interpreted in line with the ideas presented here: Experimental approaches in research on ego depletion and boredom might sometimes partially overlap, causing one construct to affect the results obtained in research that was targeted at the other construct. Beyond reflecting a potential methodological overlap, this also suggests that boredom and self-control costs closely and dynamically interact in guiding goal-directed behavior.

Concluding Remarks

To stimulate scientific progress in our understanding of self-control and boredom, we conclude with two suggestions for future research.

First, task-induced boredom should be systematically monitored in research that is informed by the strength model of self-control to better assess the validity of the ego-depletion effect. As outlined above, recognizing boredom (and related constructs, e.g., deliberate and spontaneous mind wandering; see Seli, Risko, Smilek, & Schacter, 2016) as potential mediators of self-controlled behavior is essential to better understand how people apply self-control in the lab as well as in everyday life. Figure 1 is designed to offer a working model that highlights testable hypotheses regarding the potential interplay of boredom and self-control within the context of a traditional ego-depletion study. For example, the model suggests that LCTs indeed put fewer demands on self-control, which should lead to better self-control performance (mediating role of self-control demands). However, LCTs might also cause more boredom, which should lead to impaired self-control performance (mediating role of boredom). It is important to note that the magnitude of task-induced boredom and self-control demands (and consequently the resulting performance in a subsequent self-control task) should be highly dependent on the task type and duration. Thus, although the suggested model can serve as a template for designing ego-depletion experiments that take

boredom as well as changing self-control demands into account, researchers need to be careful in accounting for the differential influences of task type and duration. Further, in light of research that points toward an inverse relationship between trait boredom proneness and trait self-control (Mugon, Struk, & Danckert, 2018), it is conceivable that both variables moderate the occurrence (and magnitude) of an ego-depletion effect. For example, people with high levels of trait boredom are likely to display impaired self-control performance after an LCT, whereas those low in trait boredom should be relatively unaffected by such a prior LCT. The inverse moderating role has been proposed for trait self-control (Muraven, Collins, Shiffman, & Paty, 2005), consistent with this hypothesis.

Second, emphasis should be placed on psychoneurophysiological approaches that have a high temporal resolution, thus allowing the dynamic interplay between self-control and boredom and the mediating psychological, neuronal, and physiological parameters to be understood. Following from the first point, the effect of a primary self-control task on subsequent self-control performance is not trivial. Moreover, task-induced boredom and self-control demands vary by task type, and a prolonged task duration might even change task characteristics (e.g., a task that was designed as an HCT might turn into an LCT as a result of learning). To better understand these temporal dynamics (which must not be linear), measures with high temporal resolution are needed to accurately track changes that occur over the course of prolonged exposure to a self-control task. In addition to self-report measures (e.g., perceived boredom, self-control demands), emphasis should be placed on physiological (e.g., heart rate variability, galvanic skin response, pupil dilation) and neuronal correlates of boredom and self-control (e.g., hemodynamic and electrophysiological changes in areas that have been implicated in boredom and self-control) to understand mechanistic similarities, differences, and potential interdependencies of both concepts. Such an approach would allow the relation between these two seemingly opposing constructs to be clarified and bring together two research areas that are reciprocally relevant.

Boredom and self-control are two highly complex constructs with great societal importance. Self-control is one of the most researched constructs in psychology, and research on boredom has experienced a recent surge in interest. In the past, inconsistent findings in ego-depletion research have sometimes been interpreted in terms of boredom. Only very recently have researchers started to concurrently investigate boredom and self-control (Milyavskaya et al., 2019). Here, we provide ideas that are intended to be a starting point for making scientific progress in understanding the intricate interdependence between boredom and self-control and to provide a working model to explain how both concepts interact. We hope this article will inspire future discussions and some much-needed research to unravel this interdependence and to clarify misunderstandings in ego-depletion research.

Transparency

ORCID iD

Wanja Wolff https://orcid.org/0000-0001-8130-0272

Note

1. Computational work indicates that the brain might have developed a preference for multiplexing (i.e., use of shared representations for different tasks) over multitasking (use of task-specific representations; Feng, Schwemmer, Gershman, & Cohen, 2014). Although multiplexing conveys many advantages, it also severely limits the capacity for performing more than one mental operation at a time because of "cross-talk," which is thought to occur when two tasks compete for the same local-processing resource at the same time (Feng et al., 2014). For example, in an incongruent Stroop trial, the default response would be to categorize the word according to its meaning, thereby causing cross-talk with the task to categorize the word according to its font color (Cohen, Dunbar, & McClelland, 1990). According to this view, rather than being limited itself, control is then used to manage the detrimental impact of cross-talk (Feng et al., 2014). The perception of effort, which arises when control is applied, can then be understood as an indicator of the costs that arise in tasks that compete for the same representations and that as a consequence require control to prevent the deleterious effects of cross-talk (Shenhav et al., 2017).

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