Supplementary Material 1

Limitation 4: The need for protocols that explore the complexity of self-control fatigue

To date, the ego-depletion literature has been dominated by studies using between-group designs based on the sequential-task paradigm. These designs are associated with several limitations (Francis et al., 2018). First, between-group designs cannot provide insights into the intra-individual dynamics of ego depletion or self-control fatigue and cannot answer several important questions such as the following: Is self-control performance linearly and negatively related to the time spent exerting an effortful self-control strategy? Is there, similar to the relation between effort and fatigue (e.g., Mlynski et al., 2021; Wright & Mlynski, 2019), a non-linear relationship (e.g., inverted U-shape) where self-control initially increases with fatigue until it reaches a threshold where self-control starts declining? Does self-control first decrease, then increases before a final decrease, similar to what could be observed in mental fatigue (e.g., Deschamps et al., 2013)? Second, and as mentioned above, the focus on the sequential-task paradigm prevents a comprehensive exploration of the three core assumptions of self-control fatigue theory. Focusing on a single method, as ego-depletion literature did, also restricts the diversity of the markers used to test the auxiliary hypotheses, thereby limiting the possibility to investigate all the effects that could further explain the phenomenon. For example, studies showed that mentally fatigued individuals can maintain similar cognitive performance as non-fatigued individuals by investing extra cognitive effort to compensate for the effects of mental fatigue (for recent reviews, see Wright et al., 2019; Wright & Mlynski, 2019, and for recent promising results, see Mlynski et al., 2021). Accordingly, mental fatigue could be characterized by a change in invested effort rather than a change in cognitive performance. If self-control fatigue is a particular type of mental fatigue, it follows that self-control performance can be maintained by investing extra cognitive effort to compensate for the effects of self-control fatigue, thereby leading to

erroneous conclusions about the absence of self-control fatigue. Therefore, to avoid such errors, markers of self-control fatigue should be diversified in future research.

Perspective 4.1: Using within-person designs and focusing on self-control across the depleting task

To date, only one study has investigated the intra-individual dynamics of ego depletion (Arber et al., 2017). This study showed a linear decline of performance during the depleting task. However, this innovative study had several limitations, such as a potentially inappropriate depletion task (i.e., letter cancellation tasks) and no measures of self-control resources or willingness. Therefore, additional studies are required to improve our understanding of the within-person dynamics of ego depletion. In 2015, an article (Job et al., 2015)was the first to discuss within-person variation in time spent sitting on chairs following a depletion task versus a control task. Precisely, the authors aimed to identify a within-person motivational shift toward rest after self-control exertion in people holding a limited-resource theory about willpower. However, in this study the authors were not interested in within-person variations of self-control act consecutively to a depletion condition or control condition, but focused on a recovery goal, which remains interesting but does not inform about within-person self-control fluctuations. A recent study initiated a research line focusing on self-control fluctuations with the development of a within-subject design to test ego depletion. The study found a significant meta-analytic effect (d = .045) despite manipulations that did not consistently affect self-control. Authors showed that self-control performance changed across the course of the experiment (e.g., participants performed worse on the 20th self-control task compared to the 1st). However, this study did not inform regarding whether self-control performance changed across (i.e., within-person and within-task analyses) each depleting task (e.g., did participants perform worse on the 32nd trials compared to the 1st?).

Despite these limitations, these three studies are promising for future self-control fatigue research based on within-person designs. Precisely, the studies should investigate the evolution of the three self-control fatigue components across the fatiguing task (e.g., repeated measures of self-control resources, willingness and capacity across the depleting task), but also across several consecutive fatiguing tasks (e.g., repeated measures of self-control resources, willingness and capacity across repeated and consecutive depleting tasks), as people may apply several consecutive self-control acts in daily life (Hofmann, Baumeister, et al., 2012; Hofmann, Vohs, et al., 2012; e.g., Hofmann et al., 2014).

Perspective 4.2: Focusing on untested auxiliary hypotheses

Moreover, we recommend focusing on the untested auxiliary hypotheses of ego depletion. Specifically, future studies should investigate the role of resources, such as perceived energy (Forestier et al., 2018; Rouse et al., 2013), perceived fatigue (Francis et al., 2018; Hirt et al., 2016), or cardiac makers (Laborde et al., 2019; Wright et al., 2019); the role of willingness, such as motivation, attention (Inzlicht & Schmeichel, 2012), vigilance (Lin et al., 2020), or decisions related to effort cost (Kool & Botvinick, 2014); and the role of self-control capacity, such as inhibition and attention (for a review, see Wagner & Heatherton, 2016). We also recommend focusing on the boundary conditions of ego-depletion emergence, as few studies have examined potential moderators of ego depletion, such as the trait of self-control (Imhoff et al., 2014), perceived success attainability (Mlynski et al., 2021; Wright & Mlynski, 2019), effort (Dang, 2016; Drummond & Philipp, 2017; Mlynski et al., 2021; Prem et al., 2016; Wright et al., 2019; Wright & Mlynski, 2019), and perceived fatigue (Vohs et al., 2021), despite the importance of such information to understanding ego depletion. As an example, the importance of self-control effort has recently been highlighted, but its role in self-control fatigue remains largely unknown. Our reanalyzes of Lin et al. (2020) and Vohs et al.'s (2021) datasets highlighted inconsistent results. Indeed, based on Vohs et al.'s (2021) data, self-

control effort was significantly and moderately associated with self-control resources (i.e., perceived fatigue) ($r = .28$, $p < .001$), and not associated with self-control willingness (i.e., perceived motivation) ($r = .03$, $p = .08$), suggesting that self-control resources and willingness are distinct from self-control effort. However, based on Lin et al.'s (2020) data, self-control effort was significantly and highly associated with self-control resources (i.e., perceived fatigue) ($r = .72$, $p < .001$), and significantly but weakly associated with self-control capacity (i.e., inhibition on a Stroop task) ($r = .02$, $p = .05$), suggesting that self-control effort and capacity are distinct, but that self-control effort and resources are similar constructs (Supplementary Materials). Future research should consider the role of self-control effort in the emergence of self-control fatigue, and investigate whether it is a fourth core concept, or whether it could be associated (e.g., new auxiliary hypotheses) with a core concept already proposed (e.g., self-control resources).

Other authors have suggested that ego-depletion sensitivity is subject to interindividual differences and that the optimal duration of the depleting task could be dependent on this sensitivity (Wolff et al., 2019). This suggestion is in line with recent findings in mental fatigue showing that individualized tasks are more fatiguing than non-individualized tasks (O'Keeffe et al., 2020). Accordingly, future self-control fatigue studies could investigate whether individual factors such as cognitive abilities and the sensitivity to task duration can be used to optimize the efficiency of fatiguing tasks (for examples of individualization processes, see O'Keeffe et al., 2020).

Perspective 4.3: Investigating a broader operationalization of self-control fatigue

In addition, we recommend investigating a broader operationalization of self-control fatigue markers. Some authors have suggested that the intraindividual variability of change in performance on a demanding task is a more sensitive indicator of mental fatigue than the traditional increase in mean reaction time (Wang et al., 2014). Based on these results, future

100 self-control fatigue studies could hypothesize that the intraindividual variability change in
101 self-control performance could be a more reliable marker of self-control fatigue than the
102 commonly used measures of central tendency.

References

Arber, M. M., Ireland, M. J., Feger, R., Marrington, J., Tehan, J., & Tehan, G. (2017). Ego Depletion in Real-Time: An Examination of the Sequential-Task Paradigm. *Frontiers in Psychology*, *8*, 1672. https://doi.org/10.3389/fpsyg.2017.01672

Dang, J. (2016). Commentary: A Multilab Preregistered Replication of the Ego-Depletion Effect. *Frontiers in Psychology*, *7*, 1155. https://doi.org/10.3389/fpsyg.2016.01155

Deschamps, T., Magnard, J., & Cornu, C. (2013). Postural control as a function of time-of-day: Influence of a prior strenuous running exercise or demanding sustained-attention task. *Journal of NeuroEngineering and Rehabilitation*, *10*(1), 1. https://doi.org/10.1186/1743-0003-10-26

Drummond, A., & Philipp, M. C. (2017). Commentary: "Misguided Effort with Elusive Implications" and "A Multi-Lab Pre-Registered Replication of the Ego Depletion Effect." *Frontiers in Psychology*, *8*, 214–221. https://doi.org/10.3389/fpsyg.2017.00273

Forestier, C., Sarrazin, P., Allenet, B., Gauchet, A., Heuzé, J.-P., & Chalabaev, A. (2018). "Are you in full possession of your capacity?". A mechanistic self-control approach at trait and state levels to predict different health behaviors. *Personality and Individual Differences*, *134*, 214–221. https://doi.org/10.1016/j.paid.2018.05.044

Francis, Z., Milyavskaya, M., Lin, H., & Inzlicht, M. (2018). Development of a Within-Subject, Repeated-Measures Ego-Depletion Paradigm: Inconsistent Results and Future Recommendations. *Social Psychology*, *49*(5), 271–286. https://doi.org/10.1027/1864-9335/a000348

Hirt, E. R., Clarkson, J. J., & Jia, L. (2016). Self-Regulation and Ego Control. In *Self-Regulation and Ego Control*. Elsevier. https://doi.org/10.1016/C2014-0-01291-9

Hofmann, W., Adriaanse, M., Vohs, K. D., & Baumeister, R. F. (2014). Dieting and the self-

control of eating in everyday environments: An experience sampling study. *British Journal of Health Psychology*, *19*(3), 523–539. https://doi.org/10.1111/bjhp.12053

Hofmann, W., Baumeister, R. F., Förster, G., & Vohs, K. D. (2012). Everyday temptations: An experience sampling study of desire, conflict, and self-control. *Journal of Personality and Social Psychology*, *102*(6), 1318–1335. https://doi.org/10.1037/a0026545

Hofmann, W., Vohs, K. D., & Baumeister, R. F. (2012). What People Desire, Feel Conflicted About, and Try to Resist in Everyday Life. *Psychological Science*, *23*(6), 582–588. https://doi.org/10.1177/0956797612437426

Imhoff, R., Schmidt, A. F., & Gerstenberg, F. (2014). Exploring the interplay of trait self-control and ego depletion: Empirical evidence for ironic effects. *European Journal of Personality*, *28*(5), 413–424. https://doi.org/10.1002/per.1899

Inzlicht, M., & Schmeichel, B. J. (2012). What Is Ego Depletion? Toward a Mechanistic Revision of the Resource Model of Self-Control. *Perspectives on Psychological Science*, *7*(5), 450–463. https://doi.org/10.1177/1745691612454134

Job, V., Bernecker, K., Miketta, S., & Friese, M. (2015). Implicit theories about willpower predict the activation of a rest goal following self-control exertion. *Journal of Personality and Social Psychology*, *109*(4), 694–706. https://doi.org/10.1037/pspp0000042

Kool, W., & Botvinick, M. (2014). A labor/leisure tradeoff in cognitive control. *Journal of Experimental Psychology: General*, *143*(1), 131–141. https://doi.org/10.1037/a0031048

Laborde, S., Lentes, T., Hosang, T. J., Borges, U., Mosley, E., & Dosseville, F. (2019). Influence of Slow-Paced Breathing on Inhibition After Physical Exertion. *Frontiers in Psychology*, *10*, 1923. https://doi.org/10.3389/fpsyg.2019.01923

Lin, H., Saunders, B., Friese, M., Evans, N. J., & Inzlicht, M. (2020). Strong Effort

Manipulations Reduce Response Caution: A Preregistered Reinvention of the Ego-Depletion Paradigm. *Psychological Science*, *31*(5), 531–547. https://doi.org/10.1177/0956797620904990

Mlynski, C., Reza, A., Whitted, M., Cox, C., Garsea, A., & Wright, R. A. (2021). Fatigue influence on inhibitory control: Cardiovascular and performance findings elucidate the role of restraint intensity. *Psychophysiology*, *58*(9), 1–18. https://doi.org/10.1111/psyp.13881

O'Keeffe, K., Hodder, S., & Lloyd, A. (2020). A comparison of methods used for inducing mental fatigue in performance research: individualised, dual-task and short duration cognitive tests are most effective. *Ergonomics*, *63*(1), 1–12. https://doi.org/10.1080/00140139.2019.1687940

Prem, R., Kubicek, B., Diestel, S., & Korunka, C. (2016). Regulatory job stressors and their within-person relationships with ego depletion: The roles of state anxiety, self-control effort, and job autonomy. *Journal of Vocational Behavior*, *92*, 22–32. https://doi.org/10.1016/j.jvb.2015.11.004

Rouse, P. C., Ntoumanis, N., & Duda, J. L. (2013). Effects of motivation and depletion on the ability to resist the temptation to avoid physical activity. *International Journal of Sport and Exercise Psychology*, *11*(1), 39–56. https://doi.org/10.1080/1612197X.2012.717779

Vohs, K. D., Schmeichel, B. J., Gronau, Q. F., Finley, A., Wagenmakers, E. J., & Albarracín, D. (2021). A Multi-Site Preregistered Paradigmatic Test of the Ego Depletion Effect. *Psychological Science*.

Wagner, D. D., & Heatherton, T. F. (2016). What Can Cognitive Neuroscience Tell Us About the Mechanism of Ego Depletion. In *Self-Regulation and Ego Control* (pp. 281–300). Elsevier. https://doi.org/10.1016/B978-0-12-801850-7.00014-7

Wang, C., Ding, M., & Kluger, B. M. (2014). Change in intraindividual variability over time as a key metric for defining performance-based cognitive fatigability. *Brain and Cognition*, *85*(1), 251–258. https://doi.org/10.1016/j.bandc.2014.01.004

Wolff, W., Sieber, V., Bieleke, M., & Englert, C. (2019). Task duration and task order do not matter: no effect on self-control performance. *Psychological Research*, *January*, 1–11. https://doi.org/10.1007/s00426-019-01230-1

Wright, R. A., & Mlynski, C. (2019). Fatigue determination of inhibitory strength and control: A babe in a bath. *Motivation Science*, *5*(1), 66–78. https://doi.org/10.1037/mot0000114

Wright, R. A., Mlynski, C., & Carbajal, I. (2019). Outsiders' Thoughts on Generating Self-Regulatory-Depletion (Fatigue) Effects in Limited-Resource Experiments. *Perspectives on Psychological Science*, *14*(3), 469–480. https://doi.org/10.1177/1745691618815654

Supplementary material 2

« From ego depletion to self-control fatigue: A review of criticisms along with new perspectives for the investigation of a multicomponent phenomenon".
Data and code are available at:
https://osf.io/4y38k/?view_only=6ceaa44fbc454b3798452f57e0e0acf6

Table 1

Correlations with confidence intervals between self-control resources (i.e., perceived fatigue), self-control willingness (i.e., perceived motivation), and self-control effort based on data from Vohs et al. (2021)

Variable	1	2
1. Perceived fatigue		
2. Perceived motivation	**.13****	
	[.09, .16]	
3. Effort	**.28****	.03
	[.25, .31]	[-.00, .07]

Note. Values in square brackets indicate the 95% confidence interval for each correlation. The confidence interval is a plausible range of population correlations that could have caused the sample correlation (Cumming, 2014). ** indicates $p < .01$.

Figure 1

Correlations between self-control resources (i.e., perceived fatigue), self-control willingness (i.e., perceived motivation), and self-control effort based on data from Vohs et al. (2021)

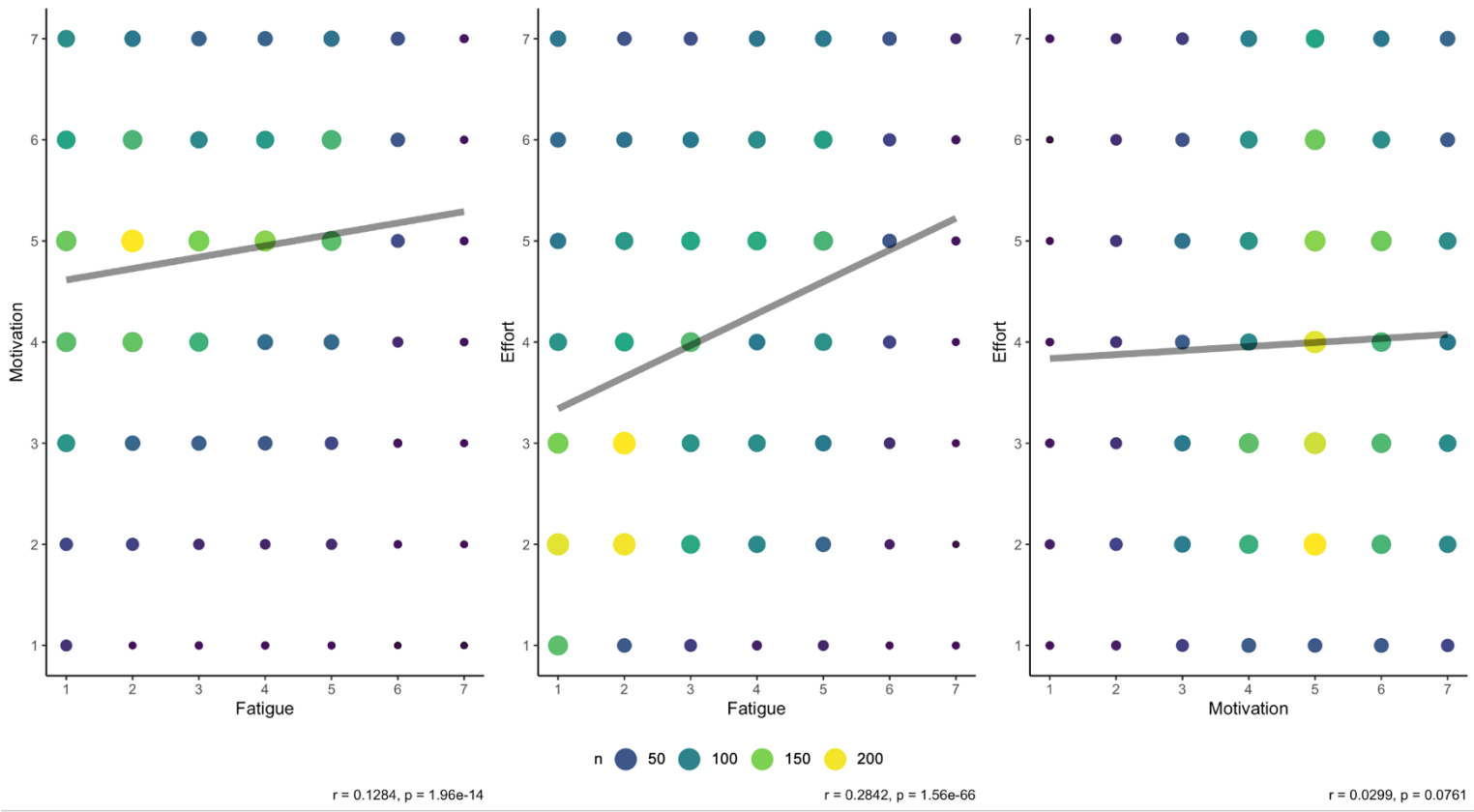

Table 2

Correlations with confidence intervals between self-control resources (i.e., perceived fatigue), self-control capacity (i.e., inhibition), and self-control effort based on data from Lin et al. (2020)

Variable	1	2
1. Perceived fatigue		
2. Inhibition	**-.03*** [-.05, -.00]	
3. Effort	**.72**** [.71, .73]	**.02*** [.00, .05]

Note. Values in square brackets indicate the 95% confidence interval for each correlation. The confidence interval is a plausible range of population correlations that could have caused the sample correlation (Cumming, 2014). * indicates $p < .05$. ** indicates $p < .01$.

Figure 2

Correlations between self-control resources (i.e., perceived fatigue), self-control capacity (i.e., inhibitory control), and self-control effort based on data from Lin et al. (2020)

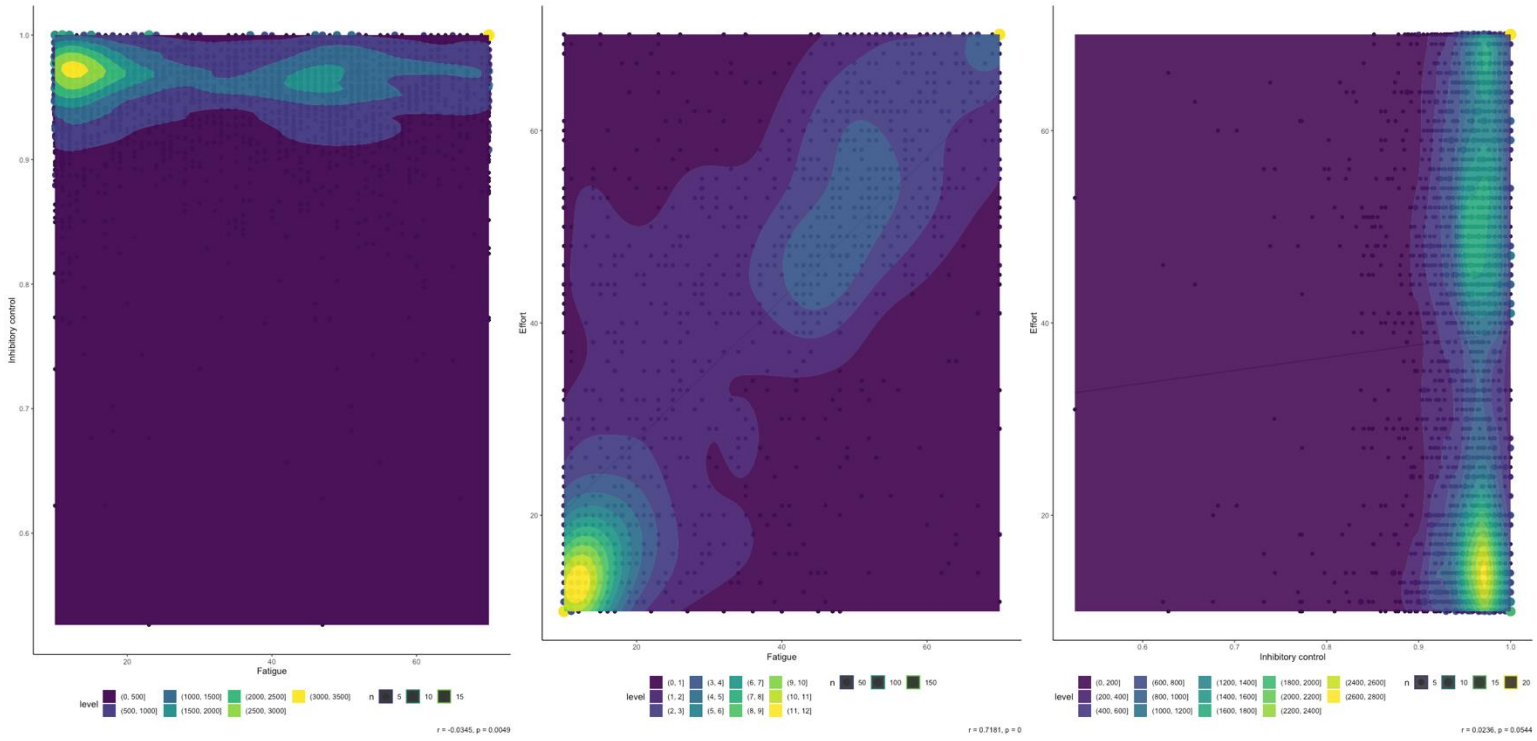

Figure 3

Shared variance between self-control capacity and self-control resources (right panel is based on data from Lin et al., 2020) as well as between self-control resources and self-control willingness (left panel is based on data from Vohs et al., 2021) suggesting small overlap