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Goal pursuit and energy conservation: Energy investment increases with task demand but does not equal it.

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Abstract

According to motivational intensity theory, energy investment in goal pursuit is determined by the motivation to avoid wasting energy. Two experiments tested this hypothesis by manipulating the difficulty of an isometric hand grip task across four levels in a between-persons (Study 1) and a within-persons (Study 2) design. Supporting motivational intensity theory's prediction, the results showed that invested energy–indicated by exerted grip force–was a function of task difficulty: The higher the difficulty, the higher the energy investment. However, the data also indicated that participants invested considerably more energy than required, questioning the primacy of energy conservation.

Keywords: motivational intensity theory, goal pursuit, energy conservation, energy investment, task difficulty, hand grip task

Goal pursuit and energy conservation: Energy investment increases with task demand but does not equal it.

What drives energy investment in goal pursuit? Most motivation theories assume that goal characteristics (e.g., the value of the goal) or the individual's need state are crucial (see McClelland, Atkinson, Clark, & Lowell, 1953; Wigfield & Eccles, 2000, for examples). They postulate, more or less explicitly, that energy investment increases in proportion to the importance of attaining the goal. Brehm's motivational intensity theory (Brehm & Self, 1989; Richter, 2013; Wright, 1996, 2008) sharply contrasts with this view by postulating that energy investment is governed by the motivation to avoid wasting resources. Brehm predicted that individuals mobilize exactly the amount of energy that is required for success because investing more than required would waste resources (e.g., Brehm & Self, 1989; Wright, 2008). He concluded that task difficulty—an indicator of the required energy —should be the direct determinant of energy investment. Motivational intensity theory acknowledges that goal characteristics and needs exert an impact on energy investment but this impact should be an indirect one. These and other factors affecting success importance should set the upper limit of the relationship between task difficulty and energy investment. Energy investment should increase as a function of task difficulty as long as the required energy is justified by the importance of attaining the goal. If success importance is not high enough, individuals should refrain from investing energy. Given that any energy investment is fruitless if task success is impossible, individuals should also not invest energy in impossible tasks.[1]

Motivational intensity theory has inspired a lot of empirical research and most

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[1]   These predictions only hold if task difficulty is fixed and known. A comprehensive discussion of all predictions of motivational intensity theory can be found in Richter (2013).

of its predictions have been extensively tested (Gendolla, Wright, & Richter, 2012, for a recent overview). However, despite more than two decades of research on the theory, the fundamental prediction that energy conservation concerns govern energy investment has not been addressed yet. A couple of studies have demonstrated task difficulty effects on cardiovascular responses (e.g., Gendolla, Richter, & Silvia, 2008; Richter, Friedrich, & Gendolla, 2008) but no study has specifically examined the question whether individuals invest only the energy that is required. The main reason for this lack of research on a central aspect of the theory are probably the measures that have been used in past research on motivational intensity theory. Drawing on work by Wright (1996), researchers have relied on sympathetic-driven cardiovascular measures to test motivational intensity theory's predictions. These measures have many advantages but it is hardly possible to use them to compare required and invested energy. Increases in sympathetic activity may reflect energy investment but it is difficult to specify the level of sympathetic activity required to successfully perform a task (e.g., to learn a series of fifteen random letters in one minute). Correspondingly, the observation that an individual's pre-ejection period—an indicator of sympathetic activity—decreases during task performance by 10 ms, does not provide any information whether this increase in sympathetic activity was required or whether the individual would also have been able to successfully cope with the task with a less pronounced increase. Fortunately, there is an alternative to cardiovascular measures that enables the comparison between invested and required energy.

Energy refers to the potential to perform work, and there is agreement on the basic processes that provide the energy for human behavior (e.g., Maughan &

Gleeson, 2010). The energy that enables bodily functions and activities stems from carbohydrates, fats, and proteins contained in the food that we consume. However, human cells cannot directly use the energy stored in these macronutrients. The energy first has to be transfered to adenosine triphosphate (ATP), the chemical energy carrier that provides the energy for all kind of cellular work (e.g., muscle contraction, transmission of neural signals, or cellular reproduction). ATP is, thus, the fuel of human activity.

In physical, isometric exercise, the amount of consumed ATP is monotonically related to exerted muscle force (e.g., Boska, 1994; Jeneson, Westerhoff, Brown, Van Echteld, & Berger, 1995; Potma, Stienen, Barends, & Elzinga, 1994; Russ, Elliott, Vandenborne, Walter, & Binder-Macleod, 2002; Szentesi, Zaremba, van Mechelen, & Stienen, 2001). To exert a high force more ATP has to be consumed than to exert a low force. Given that the economy of muscle contraction depends on many factors (e.g., muscle fiber type, contraction speed, see Russ et al., 2002; Stienen, Kiers, Bottinelli, & Reggiani, 1996; Szentesi et al., 2001, for examples), exerted force does not constitute a measure of absolute ATP consumption but under controlled conditions it enables the assessment of the relative amount of consumed ATP. Correspondingly, the assessment of exerted muscle force in an isometric task (i.e., in a task where the muscle contracts without a change in muscle length) enables the comparison of required and invested energy. If a participant has to exert a force of 80 Newton (N) for task success but exerts a force of 120 N, it is evident that she or he invested more energy than required.

Assessing exerted muscle force in isometric exercise does not only enable a

test of motivational intensity theory's basic prediction that the motivation to avoid wasting resources underlies energy investment in goal pursuit, it also enables a more precise test of motivational intensity theory's energy-related predictions. As discussed above, researchers working on motivational intensity theory have mainly relied on sympathetic-driven cardiovascular measures. If one adopts the idea that ATP is the body's energy currency, these cardiovascular measures convey little information about energy investment. Changes in sympathetic activity may parallel changes in energy investment but they do not necessarily do so. During heavy physical exercise, sympathetic activity enhances cardiac output to satisfy the increased oxygen demand of the working muscles. However, cardiac activity also increases during light physical exercise but this increase is not driven by changes in sympathetic activity. It results from decreased parasympathetic activity (e.g., Fagraeus & Linnarsson, 1976; Victor, Seals, Mark, & Kempf, 1987). Performing a light exercise certainly requires energy but this increase in energy demand is not accompanied by an increase in sympathetic activity.

There is also evidence for exaggerated sympathetic activity. Research on Obrist's cardiac-somatic uncoupling hypothesis (e.g., Obrist, 1981) demonstrated that cardiac sympathetic activity may exceed energy demand. For instance, Sherwood and colleagues found that the increase in cardiac output, heart rate, and pre-ejection period during a reaction time task exceeded the increase that one would have expected drawing on oxygen consumption (Sherwood, Allen, Obrist, & Langer, 1986). These findings show that sympathetic-driven cardiovascular measures are imperfect indicators of energy investment. Preceding studies on motivational intensity theory

thus do not constitute compelling tests of motivational intensity theory's energy-related predictions. Assessing exerted force in an isometric task enables more precise tests of these predictions.

It is of note that there is already indirect support for motivational intensity theory's hypothesis that individuals are motivated to conserve energy. A couple of physiological studies demonstrated that practice decreases energy investment (e.g., Brener, 1987; Brener & Mitchell, 1989; Lay, Sparrow, Hughes, & O'Dwyer, 2002; Sherwood, Brener, & Moncur, 1983; Sparrow & Newell, 1994). The observed reduction in energy investment with increasing practice may reflect the organisms' motivation to become more efficient to conserve energy. Other physiological studies supported the predicted relationship between difficulty and energy investment (e.g., Backs & Seljos, 1994; Carroll, Turner, & Prasad, 1986; Fairclough & Houston, 2004; Scholey, Harper, & Kennedy, 2001; Sims & Carroll, 1990; Turner & Carroll, 1985). For instance, Turner and Carroll (1985) showed that oxygen consumption—an indicator of energy investment—in a physical task is proportional to task difficulty. In their study, participants had to cycle on a bicycle ergometer at a constant pedaling rate of 50 revolutions per minute. The difficulty of the task was manipulated by varying wheel friction across four levels. Oxygen consumption significantly increased with increasing task difficulty and differed between all task difficulty levels.

Even if these physiological studies provided supporting evidence for motivational intensity theory's energy-related predictions, they suffer from two shortcomings. First, the amount of energy required for success was not assessed in these studies. Consequently, they do not enable the comparison of the required energy

with the invested energy that is crucial to test motivational intensity theory's prediction that individuals invest only the energy required for success. Second, participants were forced to perform at a certain workload level. For instance, participants in the study by Turner and Carroll (1985) had to cycle at a certain speed and against a certain resistance. They were not free to perform at their own speed or workload. It is obvious that this prevents a test of the prediction that individuals themselves choose to invest not more than required.

The aim of the present work was twofold. First, it aimed to close the gap in the literature by specifically testing motivational intensity theory's basic prediction that energy investment in goal pursuit is governed by the motivation to avoid wasting resources. In particular, I examined the prediction that individuals only invest the energy that is required and not more. Second, the work aimed to examine motivational intensity theory's energy-related predictions more accurately than in previous research using cardiovascular measures. To test these research questions, participants performed an isometric hand grip task under four different task difficulty conditions. Drawing on the assumption that energy investment is driven by the motivation to avoid wasting resources, the following two hypotheses were tested. First, energy investment (operationalized as exerted grip force) should increase with increasing task difficulty. Second, once participants know about the amount of energy that is required for success, they should invest the energy that is required and not more.

Study 1

Method

Participants and design. Seventy-two University students (mean age: 22.38

years, range: 18-53) were randomly assigned to the four cells of a one-factorial design
(task difficulty: 60 N vs. 90 N vs. 120 N vs. 150 N). All participants but one were
right-handed and 82% indicated French as their first language. The gender distribution
was as follows: 13 women and 5 men in the 60 N cell, 16 women and 2 men in the 90
N cell, 17 women and 1 man in the 120 N cell, 14 women and 4 men in the 150 N
cell. Participants received course credit for their anonymous and voluntary
participation.

Grip force measurement. Grip force (in N) was assessed with a HD-BTA
hand grip dynamometer (Vernier Software and Technology, Beaverton, OR) at a
sampling rate of 10 Hz. The dynamometer was fixed in a vertical position at the
participants' table allowing participants to use their dominant hand to squeeze it. The
basic procedure of the individual trials was as follows: First, a countdown starting at
six seconds was presented and announced the following measurement period. During
the measurement period of two seconds, exerted grip force was assessed. After the
measurement period, a feedback was presented for four seconds.

Procedure. After arriving at the laboratory, participants provided informed
consent and indicated their age, gender, handedness, and mother tongue. The
experimenter—who was hired and blind to the hypotheses—introduced the
dynamometer and participants could familiarize themselves with the device. Then,
participants' maximum force was assessed in three trials.[2] The trials included a
countdown, a measurement period, and a feedback as described above. Participants
were asked to exert their maximum force during the measurement period. During the

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2   Participants' maximum force was assessed to assure that the requested force standards did not exceed
    participants' maximum force (i.e., to assure that task success was possible). It was also assessed to control
    for individual differences in maximum force in the statistical analysis of exerted force.

feedback period, participants received a general feedback that grip force had been assessed. They did not receive a feedback about the force that they had exerted.

Participants then received instructions for the practice period. The purpose of this period was to provide participants with an opportunity to learn about the difficulty of exerting a certain force. Participants learned that the maximum force that they exert during the measurement period would be compared to a force standard and that they should try to attain this standard as precisely as possible. Depending on the respective difficulty condition, they were instructed to exert 60 N, 90 N, 120 N, or 150 N. After each measurement period, participants received a feedback regarding the difference between the maximum force that they had exerted and the force standard (e.g., "You exerted 32 Newton more than requested").

After having performed 20 practice trials, participants learned that they would now perform a different task but that the force standard would remain the same. They were informed that they would receive CHF 0.05 (about USD 0.05) for each trial where the peak force that they exert would match or exceed the force standard. Furthermore, they learned that they should try to imagine that they were squeezing a clogged Ketchup bottle to free it. If they would press the bottle hard enough, they would free the bottle and get some Ketchup. To support this cover story, a picture showing a hand holding a Ketchup bottle was displayed during the whole task. If the force exerted during the measurement period matched or exceeded the requested force, participants received a visual feedback showing a hand squeezing a Ketchup bottle that ejects Ketchup. If participants failed to exert the requested force, the default picture was displayed. A reminder ("If you exert at least XX Newton, you will

earn a reward of CHF 0.05") was presented on the top of the screen during the whole task. Participants performed 30 trials of the Ketchup task. They then performed again three maximum force trials. Finally, they were carefully debriefed and received the money that they had earned.

Data preprocessing and data analysis. Given the sampling rate of 10 Hz, 20 data points were collected during each measurement period. Peak force scores (i.e, the highest value of the 20 data points) were averaged across practice and Ketchup task trials to yield the practice and Ketchup task scores, respectively. Additionally, force-time integrals (FTI) were calculated as a second measure of energy investment by summing up all 20 data points of a given trial (Filion, Fowler, & Notterman, 1970). In contrast to peak force, FTIs reflect the energy investment during the whole two seconds of measurement. The arithmetic mean of all Ketchup task FTIs constituted the FTI task score.

An empirical test of the hypothesis that individuals invest only the energy that is required, requires the quantification of evidence for no difference between exerted force and required force. Given that p-values cannot provide this kind of information (e.g., Dixon, 2003; Johansson, 2011), I will report Bayes factors as measures of evidence. A Bayes factor (BF) provides information about the relative likelihood of the data under two competing hypotheses or models. For instance, a BF_{AB} of 4 indicates that the data are four times more likely to have occurred under model A than under model B. To test the first prediction that energy investment is a function of task difficulty, I compared a model that predicts a linear relationship between task difficulty and exerted force (difficulty model, cell weights: -3, -1, +1, and +3) with a

model that does not predict an effect of difficulty on exerted force (null model). BFs were calculated using the Bayesian information criterion (BIC) as described in Wagenmakers (2007) and Masson (2011). To test the second prediction that individuals invest only the required energy and not more, I compared the force exerted during the Ketchup task with the force standard as well as with the force exerted during practice using one-sample Bayesian t-tests (Rouder, Morey, Speckman, & Province, 2012; Rouder, Speckman, Sun, Morey, & Iverson, 2009). These t-tests contrasted the likelihood of the data under a model that predicts a difference (difference model) with the likelihood of the data under a model that predicts no difference (null model).[3] BFs will be interpreted using the nomenclature of Raftery (1995).

Results

      Practice. A $BF_{\text{DiffiNull}}$ of 6.18 x 10^{18} ($\Delta BIC = 81.93$) revealed that the peak force data were much more likely under the difficulty model than under the null model. Cell means and standard errors displayed in Table 1 and Figure 1 show that participants successfully learned during the practice trials to exert the requested force with a high precision.

      Ketchup task. The comparison of the difficulty model with the null model for exerted peak force resulted in a $BF_{\text{DiffiNull}}$ of 9.84 x 10^3 ($\Delta BIC = 18.39$). The data were 9838 times more likely under the difficulty model than under the null model providing strong evidence for the predicted impact of task difficulty on exerted peak force. The FTI data replicated this effect ($BF_{\text{DiffiNull}} = 21.27$, $\Delta BIC = 6.11$). Cell means

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3   Bayesian t-tests were conducted using a unit-information prior with known variance, the same prior that underlies the BIC calculation.

and standard errors of exerted force during the Ketchup task are shown in Table 1 and Figure 1.[4]

Contrary to the predictions, Bayesian t-tests comparing exerted peak force with the force standard provided strong to very strong evidence that participants exerted in all four difficulty conditions more force than required ($BF_{\text{DiffNull}} = 1.51$ x 10^5 in the 60-N-cell, $BF_{\text{DiffNull}} = 1.18$ x 10^3 in the 90-N-cell, $BF_{\text{DiffNull}} = 2.51$ x 10^3 in the 120-N-cell, $BF_{\text{DiffNull}} = 83.33$ in the 150-N-cell). They also found positive to very strong evidence that participants exerted a higher force during the Ketchup task than during practice ($BF_{\text{DiffNull}} = 8.33$ x 10^4 in the 60-N-cell, $BF_{\text{DiffNull}} = 6.62$ x 10^3 in the 90-N-cell, $BF_{\text{DiffNull}} = 39.84$ in the 120-N-cell, $BF_{\text{DiffNull}} = 6.54$ in the 150-N-cell).[5]

Discussion

Study 1 provided strong evidence for the predicted impact of task difficulty on energy investment: Exerted force increased as a function of increasing task difficulty. However, the study failed to provide evidence for the second hypothesis. Even if participants had learned during the practice trials to precisely exert the required force, they strongly increased their force when starting to perform the Ketchup task. Study 2 aimed to replicate Study 1 by employing a within-persons design and slightly increased force standards.

Study 2

Method

Participants and design. Forty-nine University students (mean age: 22.29

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4   Classical null hypothesis significance testing resulted in $F(1, 68) = 25.16$, $p < .001$, $MSE = 1126.29$ for the linear effect of task difficulty on peak force and $F(1, 68) = 10.56$, $p = .002$, $MSE = 642391.26$ for the linear effect of task difficulty on FTI.

5   For both experiments, all analyses were also conducted controlling for participant's maximum force. Given that this did virtually not change the results, only the uncorrected analyses are reported.

years, range: 18-45, 10 men and 39 women) performed a Ketchup task at four

different difficulty levels (70 N vs. 100 N vs. 130 N vs. 160 N). Six participants were

left-handed, 88% were native speakers. Participants received course credit for their

anonymous and voluntary participation.

Procedure. The procedure was similar to the procedure of Study 1 with the

following exceptions. All participants received all four force standards. During the

practice period, participants performed four blocks, each one consisting of 15 trials.

The force standard during the first block was 70 N, during the second it was 100 N,

during the third 130 N, and 160 N in the last block. As in Study 1, participants had to

exert the requested force as precisely as possible and were informed about the

difference between the exerted force and the force standard. During the Ketchup task,

the four force standards were also presented in different blocks. However, the order of

the blocks was random. Each block included 15 trials with the same force standard.

As in Study 1, participants could earn CHF 0.05 for each trial where the maximally

exerted force equaled or exceeded the force standard.

Results

Practice. As in Study 1, participants learned to exert the required force with a

high precision ($BF_{\text{DiffiNull}}$ = 4.12 x 10^{93}, ΔBIC = 431.11).[6] Table 1 and Figure 2 display

cell means and standard errors of exerted force during practice and the Ketchup task.

Ketchup task. The exerted peak force data were much more likely under the

difficulty model than under the null model ($BF_{\text{DiffiNull}}$ = 3.58 x 10^9, ΔBIC = 44.00)

reflecting the strong impact of task difficulty on exerted force. The FTI data replicated

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6   The mean of the individual coefficients of variation was 25.41. The ICC[1, 1] was .64.

this effect ($BF_{\text{DiffiNull}}$ = 2.28 x 10^{12}, ΔBIC = 56.91).[7]

Replicating the results of Study 1, Bayesian *t*-tests comparing exerted peak force with the force standard found positive to very strong evidence that participants exerted in all four difficulty conditions more force than required (BF_{DiffNull} = 2.75 x 10^{15} in the 70-N-cell, BF_{DiffNull} = 1.78 x 10^8 in the 100-N-cell, BF_{DiffNull} = 7.63 x 10^6 in the 130-N-cell, BF_{DiffNull} = 25.00 in the 160-N-cell). They also provided very strong evidence that participants increased exerted force from practice to Ketchup task performance (BF_{DiffNull} = 2.22 x 10^{16} in the 70-N-cell, BF_{DiffNull} = 6.67 x 10^8 in the 100-N-cell, BF_{DiffNull} = 8.70 x 10^7 in the 130-N-cell, BF_{DiffNull} = 1.18 x 10^4 in the 160-N-cell).

General Discussion

The results of the two studies provided mixed evidence for motivational intensity theory's predictions. On the one hand, the data strongly supported the hypothesis that task difficulty is a determinant of energy investment. In both studies, exerted force increased with increasing task difficulty. On the other hand, the data did not provide support for the prediction that individuals invest only the energy that is required. Participants always invested more energy than required. Despite the fact that they had successfully learned to exert the required force with a high precision during the practice trials, they increased their force during the Ketchup task trials and invested more energy than required throughout the whole task.

What are the implications of these findings for motivational intensity theory's basic postulate that energy investment in goal pursuit is governed by the motivation to

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7   Classical null hypothesis significance testing resulted in $F(1, 48)$ = 50.03, $p < .001$, MSE = 388.92 for the linear effect of task difficulty on peak force and $F(1, 48)$ = 78.99, $p < .001$, MSE = 96549.39 for the linear effect of task difficulty on FTI.

conserve resources? The strong impact of task difficulty on energy investment suggests that the motivation to conserve resources plays an important role. If individuals did not care about conserving energy, one would expect that they would always exert a high force to guarantee success. There would be no reason to adapt the level of exerted force to the difficulty of the task. The observed impact of task difficulty on exerted force is particularly remarkable given the small differences in the absolute amount of energy that were required to exert the different force standards. For example, one does not need much more energy to briefly squeeze the dynamometer with a force of 120 N than to exert 60 N. Participants would not have wasted much energy if they had always exerted the same high force (e.g., 180 N) independent of the respective trial difficulty. Even if the differences in required energy were small across the difficulty levels, participants modified their grip force in response to changes in task difficulty. These findings suggest that task difficulty and energy conservation play an important role in goal pursuit and theoretical models should account for this.

However, the data challenge the postulate that resource conservation is the sole motivation underlying energy investment. Participants always invested more energy than required, even after having learned in a practice period to invest exactly what is necessary. This is clearly in conflict with motivational intensity theory's prediction. It is tempting to come up with post-hoc explanations for this finding trying to save the theory's prediction. For instance, one might argue that the finding is due to task difficulty not being clear. Even if participants were able to exert the required force with a high precision during the practice trials, participant might have forgotten this

difficulty information when starting the Ketchup task. The task might not have been a task with a fixed difficulty but a task with an unclear difficulty. However, if this holds, one should not find any difficulty effect at all. According to motivational intensity theory, success importance (i.e., reward value) should be the sole determinant if task difficulty is unclear. Given that reward value did not differ across the four difficulty conditions, one would expect that participants exert in all four conditions the same force. This was clearly not the case. An explanation of the findings in terms of unclear task difficulty thus does not bring the findings in line with motivational intensity theory. If one argues that the findings were due to task difficulty being unclear, the observed task difficulty effect conflicts with motivational intensity theory.

One might also speculate that participants invested more energy than required to ensure that they will earn the monetary reward. Given that humans' sense of force is not accurate (Proske & Gandevia, 2012), participants might have chosen to always exert a high force to ensure success. This explanation might be correct but it does not resolve the conflict between the empirical findings and motivational intensity theory. According to motivational intensity theory, there is a sole motivation that governs energy investment in goal pursuit: the motivation to conserve energy. The theory does not consider any other motivation. Given that the motivation to ensure success is not part of motivational intensity theory, it does not enable an explanation of the findings within the scope of the theory. The supposition of a motivation to ensure success challenges motivational intensity theory but it does not question the conclusion that the observed findings conflict with motivational intensity theory.

A third explanation that one might propose to defend motivational intensity

theory's prediction is that individuals did not invest the required force because the processes required for precisely adapting the exerted force would have consumed much energy. If the energy requirement of the adaption process is higher than the energy that is wasted by exerting a higher force than required, it would actually conserve energy not to adapt exerted force. However, this explanation conflicts with the observed difficulty effect on exerted force. The explanation suggests that participants refrained from adapting their force to the force standard but the data demonstrate that participants adapted their force as a function of task difficulty. The notion that participants exerted a higher force than required because the adaption would have required (and wasted) much energy offers thus an explanation for the observed difference between exerted and required force but it fails to explain the task difficulty effect on exerted force.

It is tempting to come up with post-hoc explanations for the finding that participants invested more energy than required. However, a reasonable alternative should also be able to account for other empirical findings that support motivational intensity theory (e.g., Gendolla et al., 2012, for an overview). To my knowledge, there are no models that offer a comprehensive explanation of the finding that individuals invest more than required as well as of the other empirical findings that motivational intensity theory can explain (e.g., the interaction of reward value and task difficulty on effort mobilization, Eubanks, Wright, & Williams, 2002, or the impact of reward on effort under conditions of unclear task difficulty, Richter & Gendolla, 2009). In any case, the observation that participants invested more energy than required contests the primacy of resource conservation suggested by motivational intensity theory and

might give rise to future theory development.

A potential limitation of the presented research might be the use of exerted force as an indicator of energy investment. Given that the economy of muscle contraction depends on various factors (e.g., muscle fiber type, contraction speed), exerted force does not enable inferences about the absolute amount of consumed energy. However, given that these factors are either stable or randomly distributed across conditions in randomized experimental and within-persons designs, comparisons between conditions enable inferences regarding the relative amount of invested energy. For instance, if a participant exerted a higher force in the first trial than in the second trial it is likely that she or he expended more energy in the first trial than in the second trial. Alternative ways to assess energy investment, like measures of oxygen consumption (e.g., Sherwood, Allen, et al., 1986) or 31P magnetic resonance spectroscopy (e.g., Prompers et al., 2006), reflect the process of ATP consumption more directly but they are less comfortable for the participant and less economic. Moreover, in the case of oxygen consumption, they reflect whole body energy metabolism and cannot specifically assess the energy invested in one specific instrumental action.

The employment of a physical task might constitute another limitation of the presented research. One might wonder whether the findings from a physical task can be generalized to mental tasks. Given that motivational intensity theory has mainly been used to examine effort investment in mental tasks, employing a mental task would have created a stronger link to preceeding research on the theory. However, mental tasks have a serious drawback. With the methodology that is currently

available, it is impossible to know a priori the energy that is required to successfully execute a mental task. How much energy is needed to successfully perform a Stroop task, to read a book, or to pass an exam in motivation psychology? One could assess the energy that individuals invest in these tasks but one would not know if the invested energy reflects the minimum energy that is required or if individuals invested more than needed. There is thus a trade-off if one aims at examining motivational intensity theory's prediction that individuals invest only the energy required for task success. Using a mental task does not enable a precise test of the hypothesis. Using a physical task where one can quantify the required minimum energy enables a precise test but comes with the drawback that some researchers might doubt that the findings can be generalized to mental tasks. It is of note that motivational intensity theory does not have such doubts. The theory does not differentiate between physical and mental tasks. Its predictions should hold for any kind of goal-directed action.

The presented studies extend the literature on motivational intensity theory by demonstrating the impact of task difficulty on a measure more closely related to energy investment than the cardiovascular measures that have been used in preceding research. They also constitute the first test of the prediction that individuals do not invest more energy than required. The findings underline that energy conservation and task demand play an important role for energy investment in goal pursuit but they also challenge the prediction that energy conservation is the sole motivation that underlies energy investment in goal pursuit.

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Table 1

Cell means and standard errors (in parentheses) of exerted force.

Force Standard	Practice PF	Task PF	Task FTI
Experiment 1[a]			
60 N	67.90 (3.65)	123.73 (8.36)	1322.87 (192.65)
90 N	91.82 (2.91)	131.53 (9.02)	1699.09 (188.17)
120 N	127.87 (6.16)	153.38 (6.03)	1735.90 (161.84)
150 N	147.90 (6.10)	175.59 (8.92)	2225.64 (209.85)
Experiment 2[b]			
70 N	76.43 (2.06)	153.74 (6.05)	1565.91 (114.96)
100 N	100.81 (0.95)	160.79 (7.37)	1754.63 (124.28)
130 N	127.45 (1.01)	170.55 (5.54)	1911.29 (120.88)
160 N	154.10 (1.75)	180.19 (6.01)	2101.82 (129.37)

Note. PF = mean peak force, FTI = mean force-time-integral. [a]N = 72. [b]N = 49.
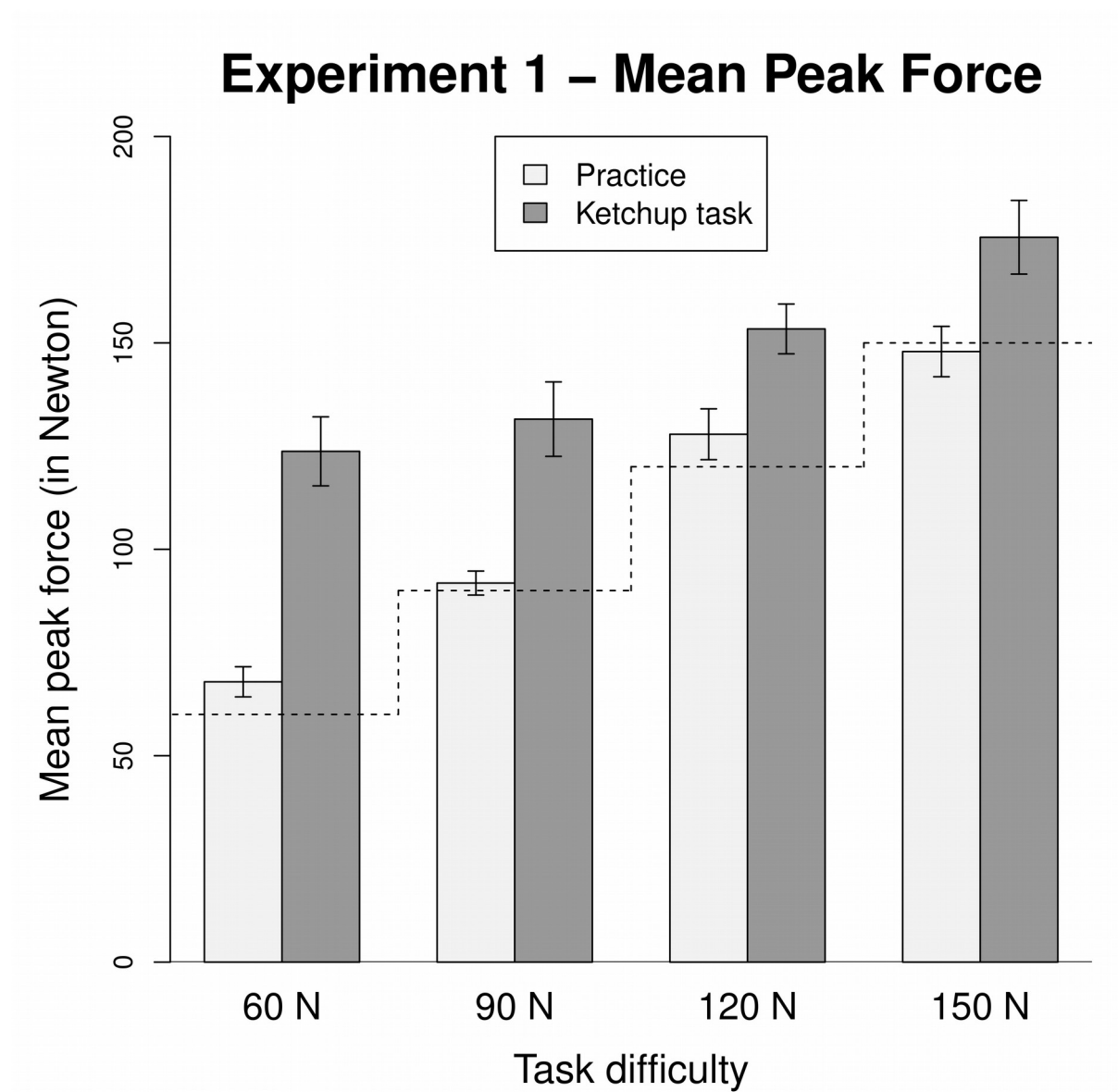
Figure 1. Mean peak force in Experiment 1. The dashed line indicates the force standards of the difficulty conditions. Error bars represent standard errors of the mean.
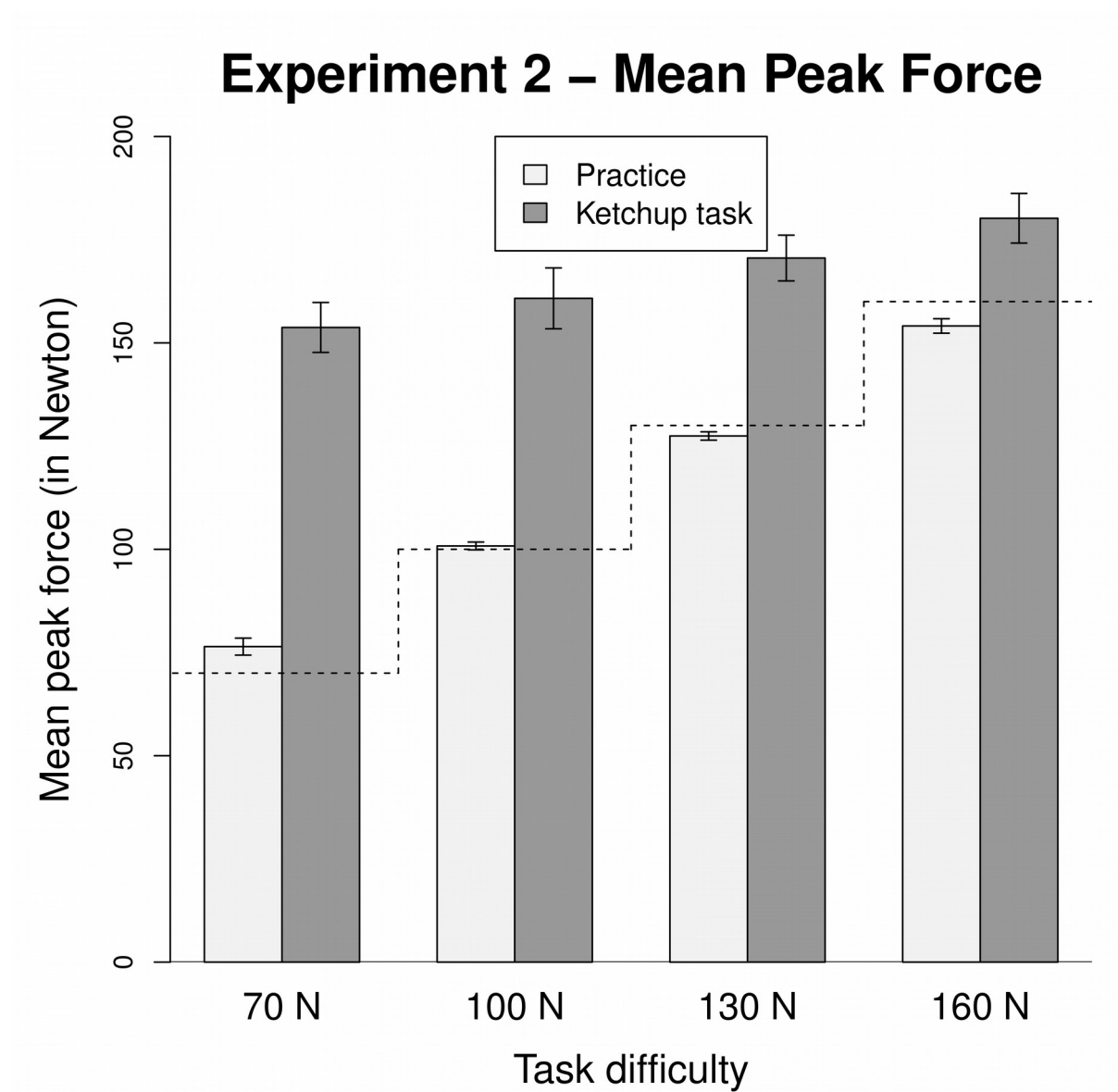
Figure 2. Mean peak force in Experiment 2. The dashed line indicates the force standards of the difficulty conditions. Error bars represent standard errors of the mean.