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Titel | Title

When Effort Feels Good: Intelligence Mindsets and the Affective Experience of Cognitive Effort

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Abstract

Effort is often conceptualized as an aversive cost that individuals seek to minimize. However, recent research suggests that effort can also be experienced as meaningful or even rewarding under certain conditions. Within the framework of implicit theories of intelligence, individuals differ in their beliefs about the malleability of ability, shaping how effort is interpreted. Whereas growth-oriented beliefs frame effort as a signal of learning and development, fixed-oriented beliefs may frame effort as a sign of limited ability. The present study examined whether intelligence mindset is associated with pleasure-related responses to cognitive effort and whether these responses depend on task difficulty and reward context. A sample of 194 university students completed an incentivized N-back task in which rewards were contingent on either effort or performance, followed by a non-incentivized Math Effort Task. During the latter, anticipatory and post-effort affective responses (wanting and liking) were assessed using trial-level self-reports and facial electromyography of the zygomaticus major muscle. Intelligence mindset was measured prior to the experiment and included as a continuous predictor. Confirmatory analyses provided no evidence that intelligence mindset predicted physiological pleasure-related responses, nor that task difficulty or reward condition moderated these associations. Exploratory analyses showed that subjective ratings decreased with increasing task difficulty, were positively related to intelligence mindset and effort enjoyment beliefs and were negatively related to baseline fatigue. Subjective and physiological measures showed little correspondence, highlighting the value of integrating multiple levels of analysis to understand how cognitive effort is experienced.

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Introduction

The exertion of cognitive effort is an essential part of everyday life, shaping how individuals approach challenges in academic, professional, and personal contexts. Many of the most complex human skills, such as problem solving, learning new languages, or mastering a musical instrument, require prolonged and sustained effort (Ericsson et al., 1993). Moreover, as the job market evolves, modern industries increasingly demand competencies such as critical thinking, self-regulation, and analytical problem-solving (World Economic Forum, 2020).

Despite its important role, many psychological and economic theories have traditionally conceptualized effort as aversive and costly, assuming that individuals are motivated to minimize its exertion whenever possible (Hull, 1943; Kool et al., 2010; Richter et al., 2016). At the same time, everyday behavior indicates a more complex picture. People frequently and voluntarily engage in effortful activities, including solving challenging puzzles, practicing the piano for hours, or pursuing intellectually demanding goals. These observations suggest that effort is not simply a resource to be conserved, but an experience whose subjective value may vary substantially between individuals and situations. In other words, effort does not carry a fixed affective value. The same level of effort may be experienced as discouraging or engaging, depending on how the individual interprets it within a given context. This implies that these individual differences in the evaluation of effort cannot be fully explained by the demands of an external task or situation alone but are equally shaped by the meanings individuals assign to effortful engagement.

One influential framework that has been proposed to account for such differences in meaning-making is the concept of intelligence mindset, which concerns individuals' beliefs about the malleability of their abilities, furthermore shaping whether effort is primarily experienced as a threat or as a signal of potential development (Dweck & Leggett, 1988). The relevance of such belief systems is likely to become particularly pronounced under conditions that place high demands on the individual through challenging tasks, or environments that change the incentive structure, making different aspects of effort salient.

To understand how effort is evaluated as aversive or rewarding, it is necessary to first consider how effort has traditionally been viewed in theories of motivation and learning.

Traditional Theories: Effort as an Aversive Cost

For much of the twentieth century, theoretical accounts conceptualized cognitive effort as a cost that individuals generally seek to minimize. Early behaviorist models, such as the “Law of Less Work”, proposed that when outcomes are equivalent, organisms prefer behaviors that require minimal effort (Hull, 1943). This assumption has been reinforced by contemporary research in motivational psychology. Kool et al. (2010) demonstrated that individuals systematically prefer tasks that demand less cognitive effort when choosing between cognitive control tasks with varying demands. “Motivational Intensity Theory” (MIT) combines these perspectives by proposing that effort mobilization is tightly regulated and increases only to the extent necessary for successful performance (Brehm & Self, 1989). According to this framework, individuals invest the minimum effort required to meet task demands and do not exceed this level unless additional incentives make doing so more valuable.

Taken together, these approaches appear to point to a coherent conclusion. Cognitive effort is something people prefer to avoid, investing it only when necessary. If effort were truly inherently aversive, individuals should exert it primarily when it is unavoidable or when external incentives compensate for its cost. While this perspective provides an important theoretical background, it fails to explain why people sometimes willingly engage in demanding activities or even experience effort as intrinsically meaningful. Addressing this discrepancy requires examining the conditions under which effort is valued rather than avoided.

Challenging the Aversive Effort Assumption

The assumption that cognitive effort is inherently aversive has repeatedly been challenged by empirical findings that can’t be explained by a purely cost-based perspective. If effort were experienced solely as unpleasant, individuals should consistently avoid demanding activities whenever less effortful alternatives are available. However, experimental evidence and everyday behavior suggest that this is not always the case. This discrepancy between theoretical assumptions of effort being inherently aversive and observable everyday behavior has been described as the Effort Paradox (Inzlicht et al., 2018). Research addressing this paradox indicates that effort is not always avoided but can, under certain conditions, become positively valued. Empirical studies have shown that rewarding individuals for effortful engagement can enhance subsequent choice preference for difficult tasks and even alter their perceived value (Clay et al., 2022; Kraus et al., 2025). Yet the positive valuation of effort does not imply that effort ceases to be costly. Effort is therefore better characterized as having a dual nature, involving both subjective costs and potential benefits.

Early theoretical work had already pointed in the direction that effort can become positively valued. The "Theory of Learned Industriousness" proposes that repeated reinforcement of effortful behavior may cause individuals to associate effort with positive outcomes (Eisenberger, 1992). Through repeated pairing with reward, effort itself may acquire reinforcing properties, functioning as a secondary reinforcer. As a result, effort may come to be positively valued through learning, increasing the likelihood that individuals engage in demanding tasks even in the absence of immediate external rewards.

This perspective is also reflected in more recent theoretical work questioning the traditional "law of least effort". Job et al. (2024) argue that this view is too narrow and does not adequately account for several functions of effort in human behavior. From an evolutionary and developmental perspective, engaging in effortful activities can serve important functions for preserving health and enabling learning and mastery.

Overall, these results challenge the notion that effort is exclusively aversive and suggest that, under certain conditions, it can be experienced as valuable or rewarding. At the same time, the observation that effort is sometimes positively valued raises an important question: If effort can contribute positively to subjective experience, why is this not consistently the case across individuals and situations? To answer this question, it is first necessary to examine the factors that shape how effort is interpreted and evaluated.

Effort as an Ambiguous Signal

The preceding evidence shows that effort cannot be understood as affectively uniform. Instead of being inherently aversive or rewarding, effort appears to be affectively ambiguous. Recent research supports this view by showing considerable variability in the way individuals approach cognitive effort. The framework on "Effort Enjoyment Belief" by Mlynski et al. (2025) demonstrates stable individual differences in beliefs about the enjoyment of cognitive effort. These differences are observed across tasks and cannot be reduced to differences in task demands or objective effort intensity. Instead, they reflect relatively stable beliefs about effort, which shape how effortful engagement is valued and interpreted. The same level of cognitive effort may be associated with different affective evaluations across individuals, suggesting that effort intensity alone is insufficient to account for variation in effort-related affect (Mlynski et al., 2025). This dissociation between effort exertion and effort evaluation suggests that the subjective meaning attributed to effort plays a central role in shaping the experience of effortful engagement. As a result, effort cannot be understood as merely a quantitative resource mobilized to meet task demands; it must also be considered an experience whose meaning is subjectively interpreted. From this perspective, effort may serve as an informational signal that prompts the interpretation and evaluation of the circumstances that elicit it (Dweck, 2017). Exerting effort may implicitly prompt questions about the purpose and significance of the activity, as well as about what sustained engagement indicates about oneself (Inzlicht et al., 2018). A general theory of motivation and personality proposed by Dweck (2017) shows that such interpretative processes are formed by overarching belief systems that organize the evaluation and integration of experiences. One of these belief systems is the intelligence mindset: depending on whether individuals tend to view their abilities as rather malleable or fixed, their interpretation, associated meaning, and valuation of effort exertion differ (Dweck & Leggett, 1988).

The informational value of effort is not constant across situations. In situations where task demands are low and success is easily achievable, effort may remain relatively uninformative and require little interpretation. In contrast, situations that require substantial effort are more likely to frame effort as meaningful and relevant (Brehm & Self, 1989; Dweck & Leggett, 1988; Inzlicht et al., 2018). Understanding when effort becomes particularly salient, therefore, requires closer attention to the role of task difficulty.

Why Difficulty Is the Critical Test Case

Motivational Intensity Theory offers a well-established framework for understanding how effort is mobilized as a function of task demands (Brehm & Self, 1989; Richter et al., 2016). As stated, individuals mobilize effort only to the extent that is necessary for successful performance, and this mobilization is further regulated by both the perceived value of success and the expectancy that success is attainable. Effort thus increases with task difficulty, but only as long as success remains plausible and sufficiently valuable. When task demands exceed what individuals perceive as achievable, or when the expected value of success no longer justifies further exertion, disengagement becomes likely.

This regulatory logic has important consequences for the psychological meaning of effort. Under conditions of high difficulty, effort is no longer optional but necessary, and its mobilization reflects an active decision to persist despite increasing demands. As a result, effort becomes highly informative. It signals commitment to the task, the perceived importance of success, and the willingness to invest resources under challenge (Brehm & Self, 1989). In this sense, difficulty transforms effort from a marginal cost into a meaningful indicator of motivational engagement. It is under these demanding conditions that the interpretation of effort becomes particularly relevant. When effort is required to sustain performance, individuals are more likely to evaluate what its exertion means, both in relation to the task and to themselves. Thus, task difficulty not only increases the amount of effort expended but also amplifies the interpretative relevance of effort. Understanding how effort is emotionally experienced under challenge therefore requires attention to belief systems that shape how effort is interpreted in difficult situations (Dweck & Leggett, 1988).

Intelligence Mindset as a Meaning System for Effort

Intelligence mindset provides a theoretical framework for understanding how individuals interpret effort. Within the broader mindset framework, individuals differ in their implicit theories about the nature of ability. A growth mindset reflects the belief that abilities are malleable and can be developed through learning, practice, and experience, whereas a fixed mindset reflects the belief that abilities are largely stable and constrained (Dweck, 2017; Dweck & Leggett, 1988). It is important to note that these beliefs are not conceptualized as categorical types, but rather as positions along a continuous dimension, with individuals varying in the degree to which they endorse growth- or fixed-oriented beliefs. These beliefs can also be domain-specific and don’t need to coincide in different domains.

Growth and fixed mindsets differ not only in how much effort individuals are willing to exert, but in what effort is taken to signify (Dweck & Leggett, 1988). Individuals with a fixed mindset, in which abilities are seen as unchangeable, tend to pursue performance goals, in which the objective is to gain favorable judgments of their competence. In this view, the need to exert effort suggests that one lacks the necessary ability, making effort both threatening and potentially aversive. In comparison, under a growth mindset, effort is interpreted as an integral part of the learning process. Their focus lies in competence enhancement, which the authors refer to as learning goals. Here, effort signals engagement with challenge and provides information about progress and development, rather than about inherent limitations (Dweck & Leggett, 1988). These differing interpretations carry direct implications for behavioral and affective responses to effortful challenge. When difficulty increases and success is uncertain, a fixed mindset is more likely to elicit avoidance, disengagement, or negative affect, as effort stresses the risk of confirming low ability. In turn, a growth mindset supports persistence in the face of challenge by framing effort as purposeful and instrumental to improvement. In this way, a growth mindset alters the meaning attributed to effort under difficulty (Dweck & Leggett, 1988). Despite some similarities, growth mindset should not be equated with a general tendency to enjoy effort (Mlynski et al., 2025). Whereas effort enjoyment beliefs describe differences in whether effort itself is experienced as pleasant or unpleasant, growth mindset implies that effort is meaningful and informative, especially when tasks are challenging. These constructs are theoretically distinct, though they may interact in shaping effort-related experiences.

In conclusion, a more growth-oriented belief system provides a meaning framework through which effort in the face of difficulty is interpreted as a signal of learning and engagement rather than an indicator of limited ability. Because difficulty makes effort unavoidable and diagnostically salient, the interpretative framework supplied by intelligence mindset should become especially relevant under challenging conditions (Brehm & Self, 1989; Dweck & Leggett, 1988). However, the meaning attributed to effort does not solely depend on individual belief systems. The situational context in which effort is exerted can further shape which aspects of effort become salient and how effort is evaluated.

Reward Contexts and Affective Processes in Effort Valuation

Situational cues may highlight particular aspects of effort and influence how effort is evaluated. One central contextual factor in achievement settings is the structure of rewards. Reward contingencies signal what is valued in a given situation and can thus frame how effort is understood (Clay et al., 2022).

A key distinction in this regard concerns effort-contingent versus performance-contingent rewards. Effort-contingent rewards link incentives to the amount of effort invested, thereby associating effort with reward and increasing its subjective value.

Performance-contingent rewards tie incentives to outcomes, such as accuracy or success, making effort primarily instrumental to goal attainment. This distinction has been central to work examining how reward structures shape engagement and affective responses towards demanding tasks (Clay et al., 2022; Kraus et al., 2025). Clay et al. showed that rewarding effort during task engagement increased subsequent preferences for more difficult tasks, even when rewards were no longer available. The influence of reward contexts extends even beyond behavioral choices and is reflected in affective processes associated with effort (Kraus et al., 2025). To summarize, reward contingencies constitute a situational frame that shapes how effort is anticipated and evaluated. By stressing either effort itself or performance outcomes, reward contexts make different aspects of effort salient, thereby influencing its affective significance. When viewed alongside task difficulty and individual meaning systems, such as intelligence mindset, reward structures form an important component of the wider context in which effort is interpreted.

Affective Processes in Effort: Liking and Wanting

Effortful engagement involves affective responses that unfold during different phases of task engagement. A useful conceptual distinction is made in this regard between wanting (anticipatory motivational processes) and liking (consummatory evaluative processes). Anticipatory processes capture the motivational pull associated with upcoming effort and reflect how attractive or aversive an effortful activity is expected to be. Consummatory processes reflect how effort is affectively evaluated during or after exertion, capturing the pleasure or displeasure experienced from having exerted effort (Nguyen et al., 2021). Differentiating between these components, therefore, allows for a more fine-grained understanding of how effort is both anticipated and experienced.

To capture these affective nuances, prior research has increasingly relied on physiological indicators that complement self-report measures. Such approaches have been used to assess both effort mobilization and affective responses during effortful task engagement, giving insight into how motivational anticipation and affective evaluation unfold over time (Kraus et al., 2025). Their recent study found physiological evidence of more positive affect during effort exertion in participants' facial expressions after they had been previously rewarded for exerting effort in an unrelated task, compared with participants who received non-contingent rewards. They used facial electromyography (fEMG) measures of the M. zygomaticus major, also known as the "smiling muscle", to capture the positive affect during effort exertion. Activity of the M. zygomaticus major is widely used as a physiological indicator of positive affect and has been linked to both anticipatory and consummatory pleasure processes, making it a suitable proxy for wanting and liking, respectively (Korb et al., 2020). These fEMG measures allow examination of effort valuation as it occurs during task performance, rather than relying on retrospective reports, thereby allowing a more precise mapping of distinct affective processes associated with effort. The present study builds upon the study design used by Kraus et al. (2025) and extends it to generate new insights.

Integrative Synthesis and Research Gap

The preceding sections converge on a multifaceted view of effort valuation that integrates motivational, affective and contextual perspectives. Instead of being a fixed cost, effort appears as an affectively ambiguous experience whose meaning depends on interpretation.

Despite recent advances in research, important gaps remain in the existing literature. Research on intelligence mindset has predominantly focused on outcomes such as performance, persistence, or task choice, with relatively little attention to the affective processes that accompany effortful engagement. This raises the following question: Under a growth mindset, is effort merely of informational value, indicating that improvement and growth are occurring, or does effort itself come to hold an intrinsic affective value?

Furthermore, research on reward contingencies has shown that effort- and performance-based incentives shape engagement and affective responses to demanding tasks. However, these effects have rarely been examined in conjunction with individual belief systems such as the growth mindset. Although both research traditions have improved our understanding of effort, their integration remains limited.

This leads to the central question of the present study: How does intelligence mindset relate to affective responses to effort, how does this relationship depend on task difficulty, and how are they modulated by effort- versus performance-contingent reward contexts? Addressing these questions through the lenses of self-reported and physiological indicators provides the foundation of the present study.

Hypotheses

Based on the previous theoretical accounts, the present study tests the following hypotheses.

H1 Intelligence Mindset – Effort Pleasure Association

Individual differences in intelligence mindset are expected to relate to affective responses to effort, independent of task difficulty and reward context

H1a Wanting.

Higher intelligence mindset scores will be associated with stronger anticipatory zygomaticus activity, independent of task difficulty and reward condition.

H1b Liking.

Higher intelligence mindset scores will be associated with stronger post-effort zygomaticus activity, independent of task difficulty and reward condition.

H2 Intelligence Mindset - Difficulty Interaction

Intelligence mindset is expected to most strongly shape affective responses to effort when effort is salient. Because high difficulty increases the interpretative relevance of effort, individual differences in intelligence mindset should predict more strongly how effort is emotionally anticipated and evaluated under challenging conditions than under easy conditions.

H2a Wanting.

The positive association between intelligence mindset and anticipatory zygomaticus activity will be stronger in high-difficulty trials than in low-difficulty trials.

H2b Liking.

The positive association between intelligence mindset and post-effort zygomaticus activity will be stronger in high-difficulty trials than in low-difficulty trials.

H3 Intelligence Mindset - Reward Condition Interaction in High-Difficulty Trials

Reward contingencies are expected to shape how effort is interpreted within the task context. Accordingly, under conditions of high task difficulty, the reward condition is expected to moderate the relationship between intelligence mindset and the affective responses to effort.

H3a Wanting.

In high-difficulty trials, the relationship between intelligence mindset and anticipatory zygomaticus activity will differ between effort-contingent and performance-contingent reward conditions.

H3b Liking.

In high-difficulty trials, the relationship between intelligence mindset and post-effort zygomaticus activity will differ between effort-contingent and performance-contingent reward conditions.

The Present Study

The present study examines how individual differences in intelligence mindset relate to affective responses to cognitive effort, how these responses depend on task difficulty, and how they are further moderated by reward contingencies. Intelligence mindset was assessed prior to the experimental tasks and treated as an individual-difference variable. To capture effort-related affective processes, this study combines self-reported pleasure ratings with physiological indicators of affect and effort mobilization. By assessing responses before and after effort, the design allows for a process-oriented examination of motivational anticipation and affective evaluation. Together, this approach provides a framework for testing the proposed hypotheses and motivates the methodological procedures described in the following section. It is important to note that this study forms part of an overarching study design carried out by the department of motivational psychology in Vienna under the direction of Univ.-Prof Dr. Veronika Job and Dr. Christopher Mlynski. Even though several students conducted their master's theses within this overarching study design, each project addressed distinct research questions based on the shared experimental framework.

Methods

Participants

The study was conducted with 194 undergraduate psychology students enrolled at the University of Vienna. Participants were recruited via the departmental participant pool and received course credit relevant to obtaining ECTS points in exchange for their participation. In addition to course credit, participants had the opportunity to earn monetary rewards during the study's incentivized phase. All participants provided informed consent prior to participation.

The sample consisted of 136 female participants, 49 male participants, and 7 participants who selected the option “other”. Participants’ ages ranged from 18 to 40 years, with a mean age of M = 22 years (SD = 3.38). Of the initial sample, seven participants were excluded from the analyses due to missing or insufficient data, resulting in a final analytical sample of N = 187 participants.

Sample size was determined by the overarching study design, and the present analyses were conducted within this predefined sample. Sensitivity power analyses were conducted using G*Power 3.1. Based on the final analytical sample of N = 187 participants, with $\alpha = .05$ (two-tailed) and a desired power of 80%, the study was able to detect effects of approximately $f^2 = .042$ both for Hypothesis 1, which tested a main effect, as well as Hypotheses 2 and 3, which tested interaction effects. Accordingly, the study was sufficiently powered to detect small-to-moderate effects, whereas very small effects may have gone undetected.

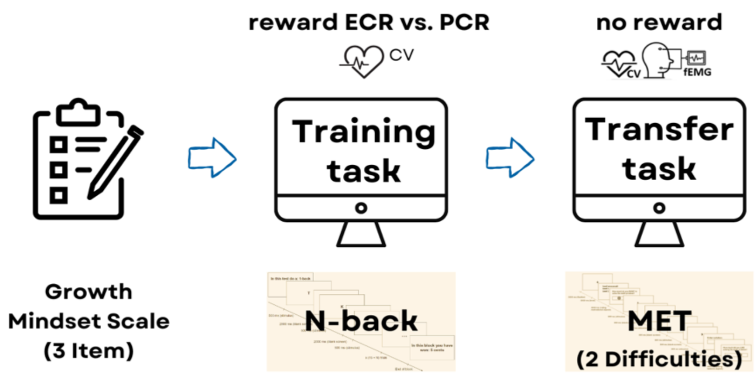
Study Design

The study used a mixed experimental design that combined between-subjects, within-subjects, and individual difference components. The reward condition served as a between-subjects factor, with participants assigned to either an effort-contingent reward condition (ECR) or a performance-contingent reward condition (PCR). Task difficulty was manipulated within-subjects at two levels (low vs. high). Intelligence mindset was assessed prior to the experimental tasks and treated as a continuous individual-difference variable.

The experimental design followed a two-phase structure. In the first phase, participants completed an incentivized task, during which the reward manipulation was implemented. During this phase, referred to as the learning phase, effort was measured using physiological indices of autonomic engagement, enabling effort-contingent rewards to be based on objective indicators of effort mobilization rather than solely on task difficulty. In the second phase, termed the transfer phase, participants completed a different, non-incentivized task, allowing for the assessment of effort-related affective responses beyond the original reward context. Affective responses to effort were assessed continuously throughout the whole study.

Figure 1

Visualization of Study Procedure



Note. Adapted from Kraus et al. (2024)

Procedure

The following procedure was used in the present laboratory study:

Pre-Assessment (Remote)

Prior to the laboratory session, participants completed a remote pre-assessment to measure stable individual-difference variables relevant to the present study. The pre-assessment included the 3-item Growth Mindset Questionnaire (Dweck et al., 1995), the Math Self-Concept Questionnaire (Benson, 1989) and the Effort Enjoyment Belief Scale (Mlynski et al., 2025). These measures were collected in advance to reduce the likelihood of demand effects and to allow the pre-assessed individual-difference measures to be incorporated as predictors in the primary analyses, with math self-concept serving as a control variable. In addition to the measures relevant to the present thesis, further questionnaires were administered as part of the broader study protocol. These additional measures are not the focus of the current analyses and are therefore not described in detail here.

Laboratory Session and Baseline Recording

Upon arrival at the laboratory, participants were briefed on the general procedure of the experiment and prepared for physiological data collection. fEMG electrodes were attached to record activity from the zygomaticus major and corrugator supercilia muscles, and cardiovascular sensors were used to assess heart rate and Pre-Ejection Period (PEP) throughout the session. After electrode placement, participants completed a baseline recording phase. During this phase, they were instructed to remain seated and relaxed while listening to calming music selected from one of five predefined playlists. The baseline phase lasted for ten minutes, allowing physiological signals to stabilize after electrode attachment.

To derive an individual reference value for effort-related cardiovascular activity, only the final two minutes of the baseline phase were used for baseline calculation. During this period, the PEP was recorded at 15-second intervals and subsequently aggregated to obtain an individual effort baseline value. This baseline served as a reference for subsequent calculations of effort-contingent rewards during the learning phase.

Learning Phase: N-back Task with Reward Manipulation

Following the baseline recording, participants completed the first experimental task. In the present study, this phase primarily served to establish the reward contingencies relevant for H3. At the beginning of this phase, participants were informed that they would perform a cognitive task and that they could earn a monetary reward during this part of the experiment. However, no information was provided regarding the specific criteria by which rewards would be determined. Before starting the task, participants completed a mood assessment using the Multi-Dimensional Mood Questionnaire (MDBF) (Hinz et al., 2012). Afterward, participants were randomly assigned to one of the two reward conditions: an effort-contingent reward condition or a performance-contingent reward condition.

Participants then completed the N-back task. Effort exertion during task performance was quantified by comparing task-related PEP with the individual baseline values obtained prior to the task. In the effort-contingent reward condition, this effort measure served as the basis of calculating monetary rewards, whereas in the performance-contingent reward condition, rewards were determined by task accuracy.

Following each block, feedback on the earned reward amount was displayed on the screen. No further interaction with the experimenter occurred during this phase.

Transfer Phase: Math Effort Task

Participants subsequently completed the MET, which served as the central assessment context of the present study. At the beginning of this phase, participants were explicitly informed that no further monetary rewards could be earned during this task. Participants then engaged in the MET. All task instructions and trial information were presented visually on the screen. Throughout the transfer phase, physiological data were continuously recorded. fEMG and cardiovascular measures were used to capture affective and effort-related responses during task engagement.

Post-Task Measures and Debriefing

After completing the MET, participants filled out a final set of questionnaires. These post-task measures included a repeated assessment of mood as well as additional questionnaires administered as part of the broader study protocol, including measures of achievement motivation and effort enjoyment belief. Following the completion of all questionnaires, participants took part in a debriefing with the experimenter, during which a series of standardized questions about task understanding, potential confusion, and prior experience with psychological experiments were asked. Participants were then informed about the general purpose of the study, any remaining questions were answered, and the laboratory session was concluded. Finally, participants received the monetary reward earned during the N-back task.

Experimental Tasks

Two different cognitive tasks were used to elicit sustained cognitive effort across the experimental procedure. Although the tasks differed in their specific implementation, both were designed to systematically vary task demands and thus induce effortful engagement.

N-back Task (Learning Phase)

Participants completed a working memory task based on the N-back paradigm (Kane et al., 2007). The N-back task requires continuous updating and monitoring of information and is widely used to elicit sustained cognitive effort. In this task, participants were presented with a continuous sequence of letters displayed one at a time on the screen. Their task was to indicate whether the currently presented letter matched the letter shown *n* positions earlier in the sequence. Task difficulty was manipulated by varying *n*, with higher N-back levels requiring participants to maintain and update more information in working memory. The task comprised four difficulty levels, ranging from 1-back to 4-back. Prior to the main task, participants completed a practice phase that introduced all difficulty levels, allowing them to familiarize themselves with the task requirements. The experimental phase consisted of multiple blocks at each difficulty level, which were presented in randomized order to prevent systematic order effects. Also, the N-back task was embedded within a reward manipulation that established distinct reward contingencies. Participants were assigned to either an effort-contingent reward condition, in which rewards were based on physiological indicators of effort investment, or a performance-contingent reward condition, in which rewards depended on task accuracy. Across conditions, feedback was provided with equal frequency, ensuring that only the basis of the reward contingency differed.

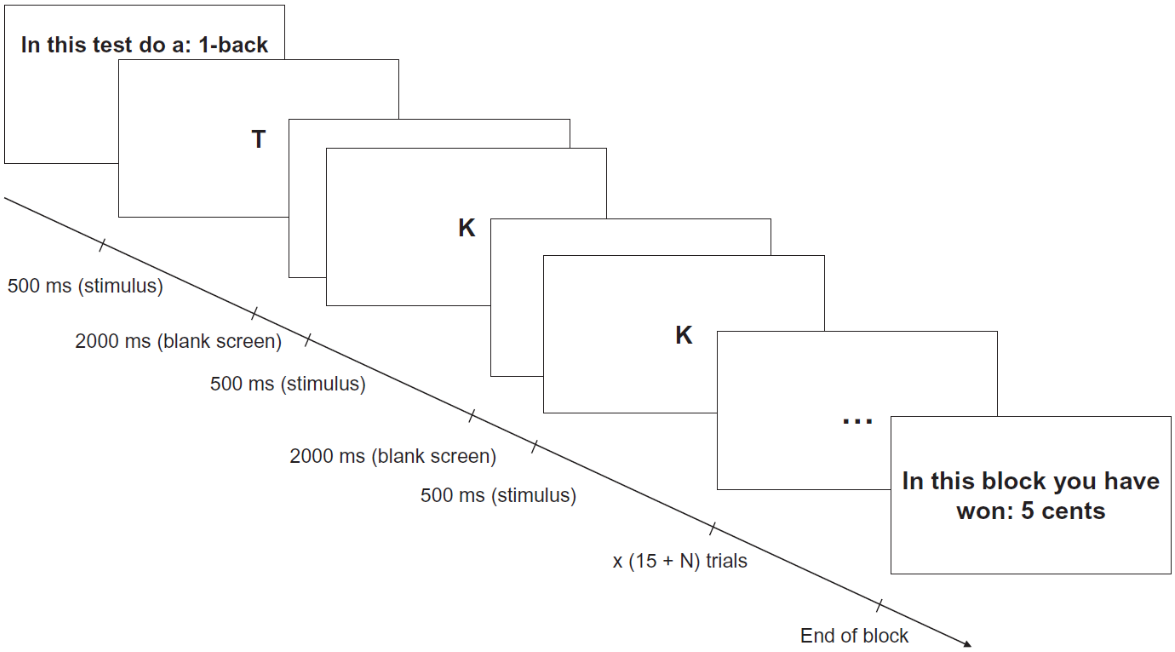
Pre-Ejection Period (PEP)

During task performance, cardiovascular activity was assessed to index physiological effort mobilization, which formed the basis for the effort-contingent reward manipulation. Pre-ejection period was used as a primary indicator of sympathetic activation associated with effort exertion. PEP reflects the time interval between ventricular depolarization and aortic valve opening and has been established as a sensitive marker of effort mobilization during cognitively demanding tasks (Albinet et al., 2024; Kelsey, 2012; Richter et al., 2016). Shorter PEP values indicate increased sympathetic activation and greater effort investment.

To determine effort-contingent rewards, PEP reactivity during the N-back task was evaluated relative to baseline levels, providing an index of effort mobilization for each participant. In the effort-contingent condition, this physiological index was used to compute reward allocation, thereby directly linking effort investment to monetary incentives. The heart rate was recorded as an additional measure of cardiovascular activation. While heart rate reflects general autonomic arousal, it is influenced by both sympathetic and parasympathetic processes and therefore was interpreted as a complementary measure.

Figure 2

Sequence of N-back trials



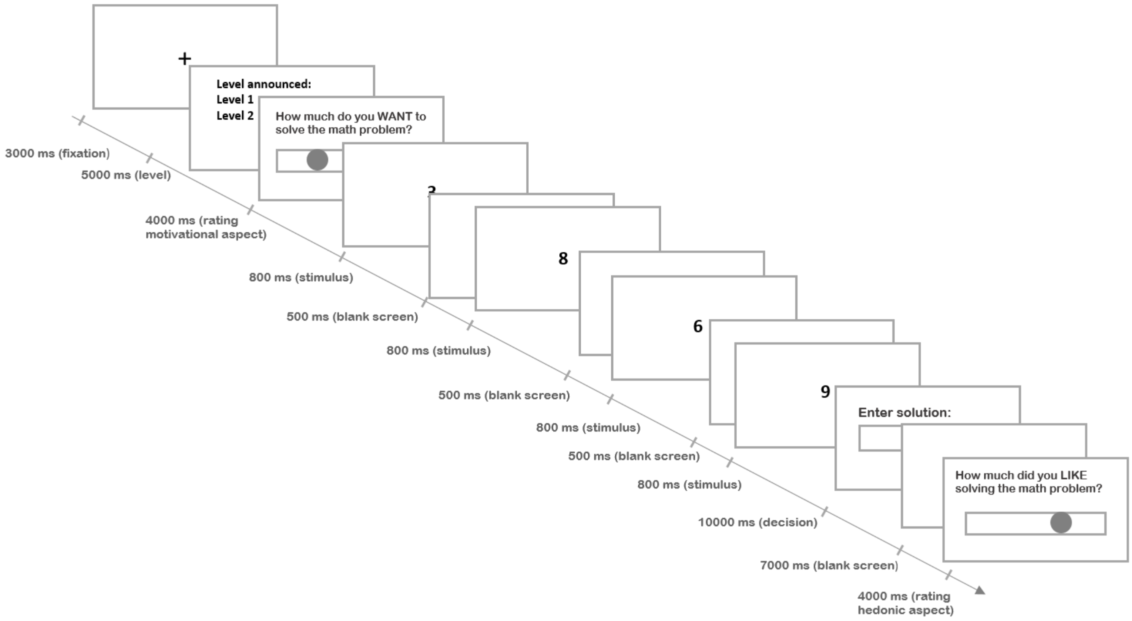
Note. Reproduced from a project proposal by Univ. Prof., PhD. Veronika Job et al.

Math Effort Task (Transfer Phase)

Participants completed a modified version of the Math Effort Task (MET), a cognitively demanding arithmetic task used to assess effort-related motivation and affective responses during effort exertion (Engle-Friedman et al., 2003). The task consisted of forty trials and included two levels of difficulty, allowing for systematic variation in cognitive effort demands within participants. Each trial followed a fixed and standardized sequence. At the start of each trial, the upcoming difficulty was announced and displayed on the screen for five seconds. Participants then provided a trial-level rating of anticipatory motivation on a continuous scale prior to task engagement. Following this rating, a fixation cross was presented for 2.5 seconds. Subsequently, four numbers were presented sequentially on the screen. Each number was displayed for 0.8 seconds, with a 0.5-second black interval between successive numbers. In low-difficulty trials, the presented numbers ranged from 1 to 9. In high-difficulty trials, the numerical range was extended to include values from 7 to 35, thereby increasing arithmetic complexity and, in turn, effort demands. Participants were instructed to mentally calculate the sum of the four presented numbers and enter their solution within a time limit of 10 seconds. After task completion, a blank screen was shown for seven seconds, followed by a trial-level rating on a continuous scale measuring the affective evaluation of the preceding task engagement. No rewards were provided during the MET, and participants were informed of the absence of monetary incentives prior to task onset.

Figure 3

Sequence of MET-trials



Note. Reproduced from a project proposal by Univ. Prof., PhD. Veronika Job et al.

Measures

The following measures were used in the present study:

Intelligence Mindset

Intelligence mindset was assessed using a short version of the Implicit Theories of Intelligence Scale originally developed by Dweck et al. (2016). The scale consists of three items measuring beliefs about the malleability of intelligence. All items reflect a fixed mindset orientation and were reverse-coded so that higher values indicate a stronger growth mindset. Participants indicated their agreement with each statement on a six-point Likert scale ranging from 1 (strongly agree) to 6 (strongly disagree). The items assess the extent to which individuals believe that intelligence is a fixed trait that cannot be substantially changed, for example, “You have a certain amount of intelligence, and you can’t really do much to change it “. The scale was translated into German using a translation-and-back-translation procedure to ensure conceptual equivalence between the original and the translated version. A composite intelligence mindset score was computed by averaging the three items, with higher scores reflecting a stronger endorsement of growth-oriented beliefs about intelligence. Internal consistency of the intelligence mindset scale was Cronbach’s $\alpha = .79$.

Math Self-Concept

Math self-concept was assessed using a four-item Math Self-Concept Questionnaire by Benson (1989). The scale was included to control for individual differences in participants’ pre-existing beliefs about their mathematical competence, which may influence task engagement and affective responses during the Math Effort Task (MET). Participants indicated their agreement with each statement on a six-point Likert scale ranging from 1 (strongly disagree) to 6 (strongly agree). Higher scores reflect a more positive self-concept regarding their mathematical ability. A composite math self-concept score was computed by averaging the four items. Internal consistency of the math self-concept scale was Cronbach’s $\alpha = .90$.

Self-Reported Pleasure (Wanting and Liking)

Self-reported affective responses to cognitive effort were assessed at the trial level during the MET using separate measures of anticipatory and consummatory pleasure. Anticipatory pleasure (Wanting) was assessed prior to each trial of the MET. Participants were asked, “How much do you want to solve the upcoming math problem?” and responded using a continuous self-report scale ranging from “not at all” to “very much”. Consummatory pleasure (Liking) was assessed after task engagement during the MET. Following each trial, participants were asked, “How much did you like solving the math problem?” and responded using the same continuous response scale.

Effort Enjoyment Beliefs

Effort enjoyment beliefs were assessed using six items capturing individual differences in the extent to which participants endorse effort as enjoyable (Mlynski et al., 2026). The scale included both positively and negatively keyed items, with negatively keyed items reverse-coded prior to analysis so that higher values consistently reflect greater enjoyment of effort. Participants indicated their agreement on a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). A composite score was computed by averaging all items, with higher scores indicating stronger endorsement of effort-enjoyment beliefs. Internal consistency of the scale was *Cronbach's* $\alpha = .85$

Fatigue

Subjective fatigue was assessed as a subscale within the Multidimensional Mood State Questionnaire developed by Hinz et al. (2012). It was measured at baseline, after the N-back task, and after completion of the Math Effort Task (MET) using a self-report questionnaire. Composite fatigue scores were computed separately for each time point by averaging across the respective items, with higher values indicating greater fatigue.

Physiological Measures

Facial electromyography was employed to capture affective responses associated with the effortful task engagement. fEMG activity was recorded from two facial muscle sites: the *zygomaticus major* muscle and the *corrugator supercilii* muscle. Activity of the zygomaticus major muscle has been consistently associated with positive affect, including experienced pleasure during task engagement (Korb et al., 2020). Recent work has demonstrated that zygomaticus activity can index positive affective responses during cognitively demanding tasks and is sensitive to differences in how effort is affectively evaluated (Kraus et al., 2025). By contrast, activity of the corrugator supercilii muscle has been linked to effort exertion and negative affective states, providing a complementary indicator of task-related strain (Korb et al., 2020). Recording from both muscle sites allowed for a more differentiated assessment of affective processes accompanying effortful engagement. During the Math Effort Task, fEMG activity was analyzed across distinct phases of task engagement. Specifically, muscle activity was examined during the announcement phase, corresponding to anticipatory pleasure (wanting) prior to task engagement, and during the post-effort phase, reflecting consummatory pleasure (liking) after effort exertion. This temporal separation aligns with theoretical distinctions between anticipatory motivational and consummatory evaluative processes (Nguyen et al., 2021).

Data Preparation and Reduction

Facial electromyography data were continuously recorded from the zygomatic major and corrugator supercilli muscles throughout the entire laboratory session. Signal acquisition was performed using a BIOPAC system, with reusable Ag/AgCl electrodes placed in accordance with standard fEMG guidelines. Impedances were kept below accepted thresholds. Raw signals were sampled at high temporal resolution and subjected to band-pass filtering and smoothing procedures commonly used in fEMG research to reduce noise and artifacts.

For the Math Effort Task, fEMG activity was segmented into predefined task phases reflecting the distinct psychological processes of anticipatory and consummatory pleasure. For each phase, muscle activity was averaged within participants. Trials showing extreme baseline deviations exceeding two standard deviations from the participants' mean were excluded. Final values were normalized relative to individual baseline activity.

Cardiovascular effort indicators were derived from pre-ejection period (PEP) and heart rate recordings. Effort-related cardiovascular indices were computed by comparing task-related values to baseline levels and aggregating across task segments, resulting in participant-level indicators of physiological effort mobilization.

Self-reported measures of anticipatory pleasure (Wanting) and consummatory pleasure (Liking) were aggregated across trials within each difficulty level. Intelligence mindset, math self-concept, and additional questionnaire measures were scored according to established procedures. All aggregated variables were screened for plausibility and distributional characteristics prior to statistical analyses. Only participants with complete data on the variables relevant to a given analysis were included.

Statistical Analyses

All statistical analyses were conducted using R (version 4.4.1). Descriptive statistics were computed for all study variables to examine distributions, central tendencies, and variability. Confirmatory hypotheses were tested using linear mixed-effects models and linear regression models. Mixed-effects models were applied to repeated measures across low- and high-difficulty conditions to account for the dependency of observations within participants, whereas analyses based on single aggregated outcomes were conducted using linear regression models. Mixed-effects models included random intercepts for participants. Fixed effects comprised intelligence mindset, task difficulty, reward condition, and their interaction terms. Math self-concept was included as a covariate to control for pre-existing differences related to numerical task engagement.

Physiological indices derived from fEMG were analyzed using aggregated scores that reflect the anticipatory and post-effort phases of task engagement. Self-reported wanting and liking were analyzed as separate outcome variables. In addition to the confirmatory analyses, exploratory analyses were conducted to examine further associations among intelligence mindset, effort enjoyment beliefs, self-reported affective responses, and physiological measures. These analyses included Pearson correlation analyses and linear regression models controlling for math self-concept. Exploratory analyses were hypothesis-generating and not corrected for multiple comparisons. Statistical significance was evaluated using an alpha level of .05 with two-tailed tests.

Results

Descriptive statistics were computed for all key study variables to provide an overview of the sample and the distributions of the central constructs. Table 1 summarizes means and standard deviations for intelligence mindset, math self-concept, self-reported wanting and liking ratings, and physiological effort-related indices across the two reward conditions. Out of the initial sample, 95 participants were assigned to the effort-contingent reward condition and 99 to the performance-contingent reward condition.

Table 1

Sample Characteristics by Reward Condition

Group	Effort (n = 95) M (SD)	Performance (n = 99) M (SD)
Age	21.74 (2.62)	22.45 (3.94)
Female (%)	71.0%	70.7%

Intelligence mindset	3.41 (1.43)	3.79 (1.39)
Math self-concept	4.24 (1.08)	4.18 (1.11)
Effort enjoyment	5.01 (0.89)	4.97 (0.93)
Baseline fatigue	2.48 (0.67)	2.51 (0.69)

Note. Values are reported as M (SD) unless otherwise indicated.

Intelligence mindset scores covered a broad range across participants (M = 3.61, SD = 1.42), indicating substantial interindividual variability in implicit intelligence beliefs. Math self-concept was moderately high on average (M = 4.21, SD = 1.09), suggesting that participants generally reported a positive valuation of their mathematical abilities. Self-reported wanting and liking ratings also showed substantial interindividual variability (SDs ranging from approximately 46 to 50; the scale was set from 0 to 100). Regarding H3, exploratory group comparisons were conducted for the main background variables to ensure comparability between the two experimental reward conditions. No significant differences emerged between the effort-contingent and performance-contingent reward groups in math self-concept, physiological effort reactivity as indexed by PEP reactivity during the N-back task, or behavioral performance measures, including total hits, false alarms, and d' as a sensitivity index (all p's > .45). Total reward earned also did not differ between conditions. Intelligence mindset scores showed a small, non-significant trend toward higher values in the performance-contingent group, $t(188.47) = -1.88$, $p = .062$, $d = -0.27$. Overall, the two conditions appeared well-balanced with respect to the central individual-difference variables.

Main Analyses: Facial EMG Responses

This section presents the confirmatory analyses. Results are reported in line with Hypotheses 1-3, focusing on anticipatory and post-effort zygomaticus activity across task difficulty and reward conditions.

Hypothesis 1: Intelligence Mindset Predicting Anticipatory and Consummatory Pleasure

Hypothesis 1 proposed that individuals with higher intelligence mindset scores would show stronger pleasure-related physiological responses before/after task engagement. Anticipatory zygomaticus activity during the announcement phase was examined as an index of wanting. Intelligence mindset was entered as a continuous predictor while controlling for task difficulty and math self-concept. Results indicated no significant association between intelligence mindset and anticipatory zygomaticus activity, $b = 0.83$, $SE = 0.65$, $t = 1.27$, $p = .207$. Although the estimated effect was positive, it was small and did not provide evidence that individuals higher in growth mindset systematically showed stronger anticipatory pleasure- related responses.

In a second model, post-effort zygomaticus activity was analyzed as an indicator of liking. Intelligence mindset again did not significantly predict post-effort zygomaticus responses, $b = -0.22$, $SE = 1.13$, $t = -0.20$, $p = .843$, suggesting no general association between intelligence mindset and consummatory pleasure-related facial activity after effort exertion. However, a significant main effect of task difficulty emerged, with higher post-effort zygomaticus activity observed under high compared to low difficulty, $b = 4.14$, $SE = 1.52$, $t = 2.72$, $p = .007$. Thus, across participants, task difficulty reliably influenced post-effort affective responding, whereas intelligence mindset did not predict either anticipatory or post-effort zygomaticus activity. Overall, these findings did not provide support for Hypothesis 1.

Hypothesis 2: Intelligence Mindset - Task Difficulty Interaction

Hypothesis 2 tested whether task difficulty moderates the association between intelligence mindset and pleasure-related responses to effort. Specifically, growth mindset was expected to be more strongly related to anticipatory and post-effort zygomaticus activity under high difficulty, when effort becomes more salient and meaningful. To examine this, interaction terms between intelligence mindset and difficulty were added to the mixed-effects models, again controlling for math self-concept.

For anticipatory zygomaticus activity (wanting), the predicted intelligence mindset-difficulty interaction was not significant, $b = 0.23$, $SE = 0.96$, $t = 0.24$, $p = .812$. This, the association between intelligence mindset and anticipatory pleasure-related facial activity did not differ between low- and high-difficulty trials.

A comparable pattern appeared for post-effort zygomaticus activity (liking). The interaction between intelligence mindset and difficulty was also non-significant, $b = -0.10$, $SE = 1.09$, $t = -0.10$, $p = .923$. This indicated that higher growth mindset was not more strongly associated with pleasure-related responses following effort exertion in difficult trials compared to easy trials. Overall, the results did not support Hypothesis 2.

Table 2

Confirmatory Mixed-Effects and Regression Models Predicting Physiological Pleasure-Related Responses

Model	Predictor	b	SE	t	p
Panel A. *Anticipatory zygomaticus*					
H1a	Intercept	105.25	1.14	92.65	< .001***
	Intelligence mindset	0.83	0.65	1.27	.207
	Difficulty (high)	1.59	1.35	1.18	.241
	Math self-concept	0.10	0.84	0.12	.903
H2a	Intercept	105.25	1.14	92.57	< .001***
	Intelligence mindset	0.71	0.81	0.88	.381
	Difficulty (high)	1.58	1.35	1.17	.243
	Math self-concept	0.10	0.84	0.12	.903
	Intelligence mindset × Difficulty	0.23	0.96	0.24	.812
Panel B. *Post-effort zygomaticus*					
H1b	Intercept	110.04	1.76	62.69	< .001***
	Intelligence mindset	-0.22	1.13	-0.20	.843

	Difficulty (high)	4.14	1.52	2.72	.007**
	Math self-concept	0.30	1.45	0.21	.837
H2b	Intercept	110.04	1.76	62.65	< .001***
	Intelligence mindset	-0.17	1.25	-0.14	.891
	Difficulty (high)	4.14	1.53	2.72	.007**
	Math self-concept	0.30	1.45	0.21	.837
	Intelligence mindset × Difficulty	-0.10	1.09	-0.10	.923

Note. b = unstandardized regression coefficient; SE = standard error.
* $p < .05$. ** $p < .01$. *** $p < .001$.

Hypothesis 3: Reward Condition as Moderator under High Difficulty

Hypothesis 3 examined whether reward context moderates the relationship between intelligence mindset and pleasure-related facial activity to effort under high difficulty. Analyses were therefore restricted to high-difficulty trials and intelligence mindset was expected to show different patterns depending on whether participants had previously experienced effort-contingent versus performance-contingent rewards. Math self-concept was once again included as a covariate.

For anticipatory zygomaticus activity (wanting), the interaction between intelligence mindset and reward condition was not significant, $b = -0.28$, $SE = 1.91$, $t = -0.15$, $p = .882$. Thus, there was no evidence that the association between intelligence mindset and anticipatory pleasure-related facial activity differed between the two reward conditions.

The same was found for post-effort zygomaticus activity (liking). Intelligence mindset did not interact with reward condition in predicting post-effort responses, $b = 0.40$, $SE = 2.62$, $t = 0.15$, $p = .880$. Thus, there was no evidence that the association between intelligence mindset and post-effort pleasure-related Zygomaticus activity differed between the two reward conditions.

Overall, these findings indicate that reward contingency did not moderate pleasure-related zygomaticus activity under high difficulty. Hypothesis 3 was therefore not supported.

Exploratory Analyses

In addition to the confirmatory analyses, exploratory analyses were conducted to further examine individual difference variables and subjective responses associated with cognitive effort during the Math Effort Task. These analyses focused on associations between intelligence mindset, effort enjoyment beliefs, fatigue, and self-reported pleasure ratings. Table 3 presents descriptive statistics and zero-order correlations for the exploratory variables.

Table 3

Descriptive Statistics and Zero-Order Correlations Among Explorative Study Variables

Variable	M	SD	1	2	3	4	5	6
1. Intelligence Mindset	3.61	1.42	—					
2. Math Self-Concept	4.21	1.09	.08	—				
3. Effort Enjoyment	4.99	0.91	.17*	.18*	—			
4. Baseline Fatigue	2.50	0.68	-.10	-.23**	-.24**	—		
5. Wanting (Self-Reported)	75.04	43.89	.14	.28***	.27***	-.21**	—	
6. Liking (Self-Reported)	78.28	40.77	.13	.28***	.27***	-.24**	.97***	—

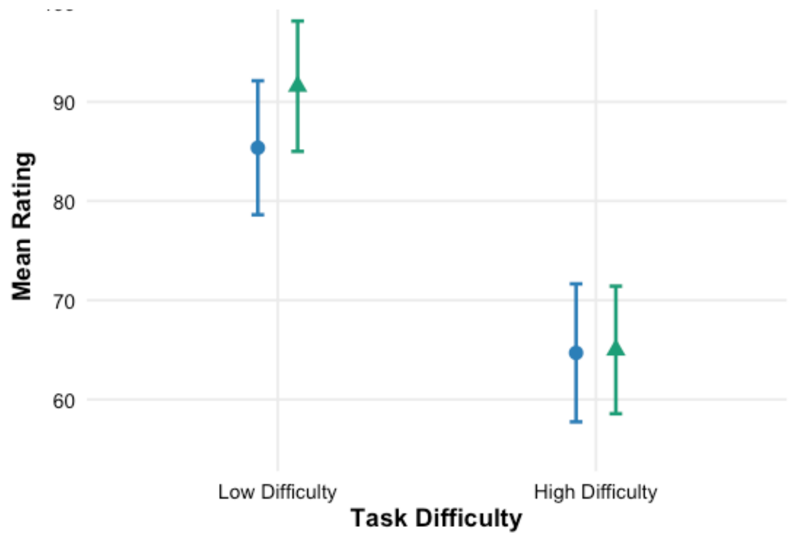
Note. M = mean; SD = standard deviation. Correlations are Pearson’s r. * p < .05. ** p < .01. *** p < .001.

Self -Reported Wanting and Liking Across Difficulty Levels

Exploratory analyses first examined self-reported wanting and liking ratings averaged across low- and high-difficulty trials during the Math Effort Task to characterize how participants subjectively anticipated and evaluated effort across difficulty levels. A mixed-effects model was fitted with measure (wanting vs. liking), difficulty (low vs. high), and their interaction as fixed effects, including random intercepts for participants. Across conditions, ratings differed descriptively between wanting and liking. Liking ratings were higher than wanting ratings overall, as indicated by a significant fixed effect of measure ($b = 6.20$, $SE = 2.60$, $t = 2.39$, $p = .017$). This suggests that participants tended to report a slightly more positive affective evaluation after completing a trial than their anticipatory motivation beforehand. Furthermore, a strong main effect of task difficulty emerged. Ratings were substantially lower under high compared to low difficulty, $b = -20.67$, $SE = 2.60$, $t = -7.97$, $p < .001$, reflecting reduced subjective pleasure-related responses when tasks required greater cognitive effort. The interaction between measure and difficulty was not significant, $b = -5.90$, $SE = 3.67$, $t = -1.61$, $p = .108$, indicating that the decline in ratings from low to high difficulty was comparable for wanting and liking. These results show that subjective effort-related pleasure and motivation decreased reliably as difficulty increased, while the differences between anticipatory and post-effort ratings were relatively small.

Figure 4

Predicted self-reported wanting and liking ratings by task difficulty.



Note. Points represent predicted values from the mixed-effects models. Error bars indicate 95% confidence intervals. Colors distinguish wanting and liking ratings.

In a second step, exploratory mixed-effects models examined whether individual differences in intelligence mindset predicted subjective wanting and liking across difficulty levels. Separate models were fitted for wanting and liking, including intelligence mindset, difficulty, their interaction, and math self-concept as fixed effects, with random intercepts for participants. For wanting, intelligence mindset showed a positive main effect, $b = 5.22$, $p = .032$, indicating that individuals with a higher growth mindset reported generally stronger anticipatory motivation across trials. Math self-concept showed a strong positive effect ($p < .001$). The interaction between intelligence mindset and difficulty was not significant, suggesting that the association between intelligence mindset and wanting did not differ between low- and high-difficulty trials. For liking, a similar pattern emerged. Intelligence mindset showed a positive main effect, $b = 4.87$, $p = .030$, while math self-concept again showed a robust positive effect ($p < .001$). The intelligence mindset-difficulty interaction was not significant. These findings indicate that higher growth mindset was associated with generally elevated subjective wanting and liking ratings independent of task difficulty.

As an additional robustness check, corrugator supercilii activity was examined as a potential marker of effort-related strain. Corrugator activity did not significantly increase from low-to high-difficulty trials (p = .199) and showed no meaningful associations with physiological effort reactivity indices or self-reported wanting and liking (all p's> .13). This, corrugator activity did not provide evidence for a robust physiological effort or strain signal in the present dataset.

Figure 5

Predicted self-reported wanting and liking ratings as a function of intelligence mindset and task difficulty

Note. Lines represent predicted values from the mixed-effects models across levels of intelligence mindset. Shaded areas indicate 95% confidence intervals. Colors represent task difficulty (low vs. high). Panel A displays wanting ratings, and Panel B displays liking ratings.

Associations Between Self-Reported Ratings and Physiological Activity

To further examine the relationship between subjective effort-related experience and physiological indicators of pleasure, exploratory correlation analyses were conducted between self-reported wanting and liking ratings and zygomaticus activity during the corresponding task phases. Self-reported wanting was not significantly related to anticipatory zygomaticus activity. Correlations were close to zero both under high difficulty (r = -.02, p = .814) and under low difficulty (r = .02, p = .779), indicating that participants' motivational anticipation of effort did not systematically correspond to physiological anticipatory activity during the announcement phase. Correspondingly, self-reported liking showed no meaningful association with post-effort zygomaticus activity. Neither high-difficulty trials ($r = .04$, $p = .577$), nor low-difficulty trials ($r = .02$, $p = .806$), showed significant correlations. Subjective effort ratings after task completion were largely independent of zygomaticus responses during the post-effort phase. These exploratory findings suggest little correspondence between self-reported pleasure ratings and fEMG indicators of positive affect according to the present data.

Effort Enjoyment Beliefs as an Additional Individual Difference Factor

Effort enjoyment beliefs were examined as a complementary construct that may capture individual differences in the affective valuation of effort more directly than intelligence mindset alone. The effort enjoyment scale showed good internal consistency (Cronbach's $\alpha = .85$), and the composite scores indicated generally high endorsement among participants ($M = 4.99$, $SD = 0.91$).

Intelligence mindset was positively associated with effort enjoyment beliefs, $r = .17$, $p = .021$, suggesting that individuals who more strongly believed in the malleability of intelligence also tended to report greater enjoyment of exerting effort. Effort enjoyment beliefs were further related to self-reported affective responses during high-difficulty trials. Higher effort enjoyment significantly predicted stronger liking ratings, $b = 14.40$, $SE = 3.44$, $t = 4.19$, $p < .001$, as well as stronger wanting ratings, $b = 14.58$, $SE = 3.77$, $t = 3.87$, $p < .001$, while controlling for math self-concept. In contrast, effort enjoyment did not predict post-effort zygomaticus activity under high difficulty, $b = 1.17$, $SE = 2.04$, $t = 0.57$, $p = .567$, indicating that its association was primarily evident in subjective ratings rather than physiological activity.

Model comparisons suggested that effort enjoyment accounted for variance in self-reported pleasure beyond intelligence mindset. While intelligence mindset initially predicted self-reported liking and wanting ratings, these effects were reduced to non-significance once effort enjoyment was included, whereas effort enjoyment remained a robust predictor. Adding effort enjoyment significantly improved model fit for both liking, $F(1, 188) = 15.23$, $p < .001$, and wanting, $F(1, 188) = 14.94$, $p < .001$.

In an additional combined model focusing on high-difficulty trials, wanting and liking ratings were analyzed jointly to test whether effort enjoyment beliefs were differentially related to anticipatory versus post-effort pleasure. Effort enjoyment emerged as a strong positive predictor of ratings across both measures, $b = 15.52$, $SE = 3.56$, $t = 4.36$, $p < .001$, while math self-concept remained a significant covariate, $b =$

10.45, $SE = 2.09$, $t = 5.00$, $p < .001$. Importantly, the interaction between measure and effort enjoyment was not significant, $b = -1.12$, $SE = 4.99$, $t = -0.23$, $p = .822$, indicating that effort enjoyment was similarly associated with both wanting and liking responses under high difficulty.

Fatigue as a Momentary Affective State

As an additional exploratory analysis, momentary fatigue was examined as a potential state-related factor influencing effort valuation during the experiment. Fatigue ratings were assessed at baseline and again after completion of the Math Effort Task. Composite fatigue scores were calculated by averaging the fatigue items at each measurement point.

A paired-samples t-test revealed a substantial increase in fatigue over the course of the experiment, $t(192) = -16.81$, $p < .001$. On average, fatigue increased by approximately 1 scale unit from baseline to the post-task measurement, indicating that the MET reliably induced mental fatigue across participants.

To examine whether baseline fatigue was related to subjective effort-related evaluations, a mixed-effects model was fitted predicting self-reported wanting and liking ratings across trials. The model included difficulty, baseline fatigue, and their interaction as fixed effects, as well as measure (wanting vs. liking), with random intercepts for participants. Consistent with previous exploratory analyses, difficulty had a strong negative effect on ratings ($p < .001$), indicating lower pleasure-related responses during high-difficulty trials. Baseline fatigue significantly predicted subjective ratings, $b = -16.81$, $p < .001$, such that participants reporting higher fatigue at baseline generally reported lower wanting and liking ratings during the task. In addition, a significant difficulty-by-fatigue interaction emerged, $b = 6.06$, $p = .025$, indicating that fatigue-related differences in ratings were attenuated under high task difficulty. Finally, exploratory regression analyses examined whether baseline fatigue was related to physiological indicators of effort and affect. Baseline fatigue showed no meaningful associations with corrugator activity, post-effort zygomaticus activity, or cardiovascular effort reactivity. Thus, fatigue appeared to be related primarily to subjective effort evaluations rather than to physiological measures.

Together, these exploratory findings suggest that momentary fatigue may influence how effort is subjectively evaluated during cognitively demanding tasks, while showing little correspondence with the physiological indices assessed in the present study.

Discussion

The presented study examined whether intelligence mindset is associated with pleasure-related physiological responses during the exertion of cognitive effort, and whether these associations depend on task difficulty or reward context. Across the confirmatory analyses, no evidence was found in support of Hypotheses 1-3. Intelligence mindset did not significantly predict anticipatory or post-effort zygomaticus activity, and neither task difficulty in general nor reward condition under high difficulty moderated the associations. Thus, the proposed link between implicit intelligence beliefs and immediate fEMG indicators of pleasure during effortful engagement was not supported in the present dataset.

In contrast to the not supported confirmatory analyses, exploratory analyses provided additional context for the broader pattern of results. Subjective wanting and liking ratings decreased reliably with increasing task difficulty, indicating that participants experienced effortful trials as less pleasurable and had less motivation to solve them than easy trials, which aligns with classical accounts conceptualizing effort as a subjective cost (Kool et al., 2010; Richter et al., 2016).

However, these self-reported affective responses showed little correspondence with fEMG activity, suggesting a dissociation between subjective evaluations and physiological indices of affect. Effort enjoyment beliefs emerged as a robust predictor of self-reported responses, accounting for variance in wanting and liking beyond intelligence mindset. Baseline fatigue was also negatively related to subjective liking and wanting ratings in the MET. Furthermore, throughout the experiment, fatigue showed a significant change, indicating that the experiment was mentally exhausting, which in turn may have affected the cognitive-emotional appraisal of effort.

These findings suggest that individual differences in how effort is subjectively valued may be more strongly reflected in self-reported ratings than in the fEMG measures assessed here, providing an important starting point for interpreting the null physiological effects.

Intelligence Mindset and Immediate Physiological Pleasure Responses: Interpreting the Null Effects

One first interpretation of the observed null findings may concern the laboratory context in which the study was conducted. The relevance of intelligence mindset for emotional effort valuation may depend strongly on whether effort is experienced as meaningful. Growth mindset should be most consequential when effort functions as a signal of development, identity, or long-term goals. In everyday contexts, effort is often embedded in sustained projects and self-relevant domains, where challenge can be interpreted as progress. However, the MET represents a constrained laboratory task with limited personal significance for many participants. The subjective value of engaging in difficult arithmetic trials is therefore likely low or at least highly heterogeneous. Under such conditions, effort may not be experienced as "I am improving", but rather as externally imposed cognitive demand. Consequently, even if intelligence mindset shapes how individuals interpret effort and challenge, the strength of its effects may depend on situational cues and contextual affordances (Dweck, 2017). In highly constrained laboratory settings, where effort is short-term and only weakly embedded in personally meaningful goals, dispositional beliefs may exert a reduced influence on immediate physiological responses. Nevertheless, this interpretation fails to explain the exploratory results indicating a positive relationship between intelligence mindset and self-reported measures of liking and wanting in the MET.

The discrepancy between physiological findings and self-reports might suggest one of two interpretations: (1) Beliefs such as the Intelligence Mindsets or Effort Enjoyment Beliefs might, rather than being reflected at the level of physiological emotional responses, be more closely tied to the cognitive appraisal of these responses. (2) Our physiological measurements of affect did not capture what we intended to, which will be discussed later on. First, intelligence mindset is primarily conceptualized as a socio-cognitive belief system about the malleability of abilities, shaping how individuals interpret challenge, effort and setbacks (Dweck, 2017; Dweck & Leggett, 1988). Such beliefs might be more distal to momentary physiological responses in laboratory trials, as their influence unfolds through processes of appraisal, meaning making, and goal commitment, which are mostly constrained in classical laboratory settings. According to appraisal theories of emotion, beliefs shape how individuals interpret the significance of events for their goals and well-being (Lazarus, 1982).

Viewed in this way, intelligence mindset may influence how effort and challenge are evaluated at a cognitive level, which may be reflected more strongly in subjective evaluations than in immediate physiological responses within short laboratory trials.

Psychological Determinants of Effort Valuation

Beyond the Confirmatory Analyses, which yielded no significant results, the exploratory analyses suggest that effort-related pleasure may emerge from the interplay of various psychological processes that shape how effort is evaluated and experienced. The following section, therefore, integrates individual belief differences, contextual meaning, reward contingency, and mood as complementary determinants of effort valuation.

Individual Differences in Subjective Effort Valuation

An important exploratory insight of the present study was that, although intelligence mindset showed no stable associations with physiological pleasure-related indices, it was indeed related to self-reported liking and wanting ratings. Participants with stronger growth-oriented beliefs tended to report higher subjective motivation and enjoyment when engaging in cognitive effort. This finding suggests that intelligence mindsets may influence how effort is consciously evaluated, even if such differences are not directly reflected in immediate physiological affective responses. A closer inspection of the subjective ratings across task difficulty further illustrates this pattern. As shown in Figure 5, the association between intelligence mindset and subjective evaluations appeared stronger for high-difficulty trials than for easy trials. Whereas easy trials were evaluated relatively positively across participants, evaluations of difficult trials varied substantially as a function of intelligence mindset. Individuals with more fixed-oriented beliefs reported markedly lower wanting and liking ratings for difficult trials, whereas individuals with more growth-oriented beliefs evaluated these trials more positively. This pattern aligns with the theoretical reasoning outlined in the introduction, which holds that task difficulty is a critical context in which effort becomes diagnostic. When tasks are easy, exerted effort provides little information about ability or learning potential. Under conditions of high difficulty, effort may become a more salient cue for interpreting performance and challenge.

The associations between intelligence mindset and self-reported wanting and liking ratings were, however, substantially reduced once effort enjoyment beliefs were included, which emerged as a more robust and proximal predictor of self-reported pleasure responses during cognitive effort. Effort enjoyment accounted for meaningful variance in subjective affective evaluations beyond intelligence mindset, suggesting that more specific beliefs about the affective value of effort may capture the immediate experiential component of effort engagement more directly than broad intelligence-related mindsets. Mlynski et al. (2025) emphasize that effort enjoyment beliefs represent stable individual differences in how effort is valued, and they show that these beliefs predict both behavioral and physiological indicators of seeking. Even though the physiological effects could not be observed in the present study, effort enjoyment was indeed closely tied to subjective pleasure ratings and even more so than intelligence mindset.

Individual effort enjoyment beliefs may be shaped by learning history and reward contingencies. Clay et al. (2022) demonstrate that rewarding cognitive effort can increase the intrinsic value of mental labor, leading individuals to prefer more demanding tasks even after rewards are removed. This suggests that effort valuation is not fixed, but can be modified through experience, particularly when effort itself is reinforced. Kraus et al. (2025) similarly show that effort-contingent reward contexts can enhance physiological pleasure-related responses following effort exertion. Together, these findings support the idea that effort enjoyment beliefs may partly reflect learned associations through which effort becomes linked to reward and positive affect. This is consistent with the theory of “learned industriousness”, in which effort is repeatedly paired with positive rewards and thus acquires the characteristics of a secondary reinforcer (Eisenberger, 1992). Developmental work on intelligence mindsets suggests that the meaning individuals assign to effort is shaped early through socialization processes, particularly by whether children are praised by parents or teachers following success for their inherent ability or their invested effort (Haimovitz & Dweck, 2017). From this perspective, growth mindset may contribute to long-term meaning-making around effort, which could indirectly foster greater enjoyment of challenge. Thus, an individual’s effort-enjoyment beliefs could be developed alongside intelligence mindsets through socialization, especially through praise for effort.

Context Dependence and Subjective Value

Beyond individual differences in intelligence mindset and effort-enjoyment, the present findings also highlight the importance of contextual factors that shape the subjective value of effort. Notably, the exploratory analyses revealed a clear pattern: subjective wanting and liking ratings decreased systematically as task difficulty increased. Participants therefore experienced more demanding trials in the Math Effort Task as less attractive and less pleasurable than easier trials. This pattern suggests that, within the present paradigm, cognitive effort was primarily experienced as a subjective cost rather than as an intrinsically rewarding activity.

Laboratory research on effort has traditionally relied on cognitively demanding tasks because they allow precise experimental control. However, such paradigms may capture only a subset of experiences of effort, particularly those associated with effort costs rather than with effort meaning. Therefore, they may tap into constructs such as persistence or frustration tolerance rather than genuine enjoyment of effort. The theoretical premise that effort can become enjoyable is typically grounded in contexts where effort is connected to meaningful goals, learning, or valued outcomes. In such situations, exertion can signal progress, mastery, or personal development. Laboratory paradigms such as the Math Effort Task, however, represent short-term, externally imposed challenges that may lack motivational meaning. Consequently, these paradigms may not always instantiate the psychological conditions under which effort becomes intrinsically valued (Inzlicht et al., 2014, 2018).

While effort enjoyment beliefs emerged as a robust predictor of subjective wanting and liking ratings, these associations were observed in an abstract, decontextualized paradigm. In a way, these effort contexts may even resemble the meaning of effort under a fixed mindset as cost or threat, raising the question whether repeated exposure to externally imposed cognitive effort with limited personal meaning could contribute to more fixed interpretations of effort. Related work by Job et al. (2024) suggests that low-construal level laboratory settings can produce an effort-failure contingency rather than an effort-reward contingency, fostering avoidance rather than intrinsic valuation. Under certain circumstances, such as repeatedly engaging in cognitive tasks that lack novelty, feedback, or meaning, individuals might exhibit behavioral patterns of effort avoidance (Job et al., 2024). This pattern is consistent with the present findings, which show lower self-reported wanting and liking ratings for high-difficulty trials in the Math Effort Task.

Reward Contingencies

As previously discussed, reward contingencies have been shown to influence the appraisal of effort (Clay et al., 2022; Kraus et al., 2025). In the confirmatory analyses of the present study, reward condition did neither moderate the association between intelligence mindset and pleasure-related fEMG indices, nor the self-reported liking and wanting ratings. Moreover, independent of intelligence mindset, no stable differences emerged between effort-contingent and performance-contingent reward contexts in anticipatory or post-effort zygomaticus activity. These results contrast with the aforementioned empirical evidence. Harmon-Jones et al. (2020) state that positive revaluation of effort outcomes primarily occurs when individuals perceive their effort as instrumental for obtaining the reward. When contingency is weakly perceived or doubted, effort may fail to translate into enhanced reward valuation signals. Given that the reward manipulation was brief and largely implicit, participants may not have fully internalized the effort-reward contingency, thereby limiting the emergence of physiological or self-reported indicators of pleasure. This interpretation is also consistent with informal observations during data collection, suggesting that the reward structure may have elicited frustration or demotivation in some participants, which could further dilute any subtly pleasure-related signal rather than amplify it. Applied to the present findings, this implies that the absence of robust zygomaticus differentiation and self-reported ratings across reward contexts may reflect limited perceived effort-reward contingency rather than the irrelevance of reward structure itself.

It is also possible that the use of monetary rewards in the present paradigm may have limited the emergence of effort-related pleasure signals. Research within Self-Determination Theory has shown that external rewards can, under certain conditions, undermine intrinsic motivation when they are perceived as controlling rather than competence-supportive (Deci et al., 1999). In contrast, effort praise and mastery feedback may strengthen the perceived value of effort by emphasizing progress and competence rather than external incentives (Albrecht et al., 2014; Mueller & Dweck, 1998).

More broadly, meta-analytic evidence on growth mindset interventions indicates that their effects are typically small and highly context-sensitive, rather than consistently robust across contexts (Burnette et al., 2023). Even though effort-contingent rewards are not identical to growth mindset interventions, which focus more on direct praise and conscious work on belief systems, they could still be seen as a more proximal form of effort-valuation intervention, sharing the characteristics of small, context-sensitive effects.

Mood and Fatigue

The last factor influencing effort valuation discussed here regards momentary affective states. In the present study, momentary affective state was operationalized using self-reported fatigue levels assessed during the experiment. Participants reported substantially increased fatigue after completing the Math Effort Task, indicating a systematic shift in affective state over the course of the experiment. This makes sense, since the tasks are employed to induce cognitive effort, which in turn causes fatigue. Nevertheless, baseline fatigue levels significantly predicted subjective ratings of wanting and liking, such that participants experiencing higher fatigue generally reported reduced pleasure-related evaluations of cognitive effort. This association was attenuated under high task difficulty, suggesting that increasing task demands partially constrained mood-related differences in subjective valuation. Notably, these fatigue effects were confined to subjective evaluations and did not extend to physiological indicators. Baseline fatigue showed no meaningful associations with corrugator activity, zygomaticus responses, or cardiovascular effort reactivity. Thus, fatigue appeared to influence how effort was appraised and evaluated.

This pattern aligns closely with the Mood-Behavior-Model proposed by Silvestrini and Gendolla (2009b, 2009a), which conceptualizes mood as informational input guiding task appraisal. According to this framework, affective states influence perceived task demand and the subjective value of effort exertion, thereby shaping motivational engagement indirectly through evaluative processes rather than directly influencing physiological responses to effort. In this view, mood affects the valuation of effort by influencing whether effort is interpreted as worthwhile or aversive in a given situation.

Integrating these findings within the broader results of the present study suggests a multi-level account of effort experience. Whereas intelligence mindset and effort enjoyment beliefs reflect relatively stable orientations toward effort, momentary affective states may determine whether effort is experienced as rewarding or aversive in a specific context.

Measurement Considerations: What does Facial EMG capture?

While the preceding sections focused on psychological factors that may shape the subjective experience of effort, the dissociation between self-reported evaluations and physiological responses also raises the possibility that methodological factors contributed to the observed pattern of results. In particular, the present findings invite closer consideration of what facial electromyography actually captures in cognitively demanding effort paradigms.

While self-reported wanting and liking varied systematically with task difficulty and showed clear associations with subjective belief-based constructs, including intelligence mindset and more proximally effort enjoyment beliefs, the fEMG indices showed little correspondence with these subjective evaluations. This dissociation suggests that zygomaticus major activity may not have captured the intended pleasure-related processes in the present cognitive effort paradigm.

Facial electromyography, and zygomaticus activity in particular, is often interpreted as an implicit indicator of positive affect (Korb et al., 2020; Kraus et al., 2025). However, evidence from cognitive effort paradigms indicates that its validity as a marker of pleasure may be substantially more context-dependent than commonly assumed. For instance, Devine et al. (2023) reported that zygomaticus activity was not reliably influenced by either problem difficulty or reward magnitude during cue presentation or effort exertion, whereas corrugator activity increased linearly with cognitive demand and was attenuated by higher reward incentives, suggesting a more robust sensitivity to aversive effort costs than to positive hedonic signals. This asymmetry aligns with the possibility that cognitively demanding tasks elicit clearer physiological cost signals than pleasure-related responses. Nonetheless, neither zygomaticus nor corrugator activity showed the assumed associations with effort exertion and its relation to intelligence mindset.

A further complication concerns the temporal placement of fEMG measurement. Kraus et al. (2025) found increased zygomaticus activation primarily after effort completion rather than during task engagement, and this post-effort activity predicted subjective liking ratings specifically in the effort-contingent reward group. In their paper, Kraus et al. (2025) explicitly discuss that such post-effort responses may reflect processes tied to having exerted effort rather than pleasure during effort itself, and they consider alternative explanations such as the contrast hypothesis, where termination of an aversive task produces an affective rebound. In their study, post-effort zygomaticus activity positively correlated with the corresponding self-reports, making the contrast hypothesis an unlikely explanation, whereas in the present study, it remains a plausible interpretation due to the dissociation between self-reported and physiological assessments. In short, the post-effort fEMG window used may have captured relief from effort offset rather than intrinsic enjoyment of effort.

Finally, physiological responses in cognitive effort contexts appear highly sensitive to broader task framing and affective meaning. Work integrating the Motivational Intensity Theory and the Mood-Behavior-Model shows that effort mobilization, and consequently its appraisal, depend not only on objective difficulty but also on hedonic incentive and the subjective appraisal of task demand, which in turn can be affected by current mood states (Silvestrini & Gendolla, 2009b). These findings reinforce the idea that physiological signals may be shaped by contextual factors beyond difficulty and intelligence mindsets alone, which may contribute to heterogeneous fEMG effects across paradigms.

All in all, these measurement considerations complicate the interpretation of null physiological findings. The absence of intelligence mindset associations with fEMG responses does not necessarily indicate that motivational beliefs are irrelevant to effort-related pleasure and motivation, but rather that the physiological indices assessed here captured a different facet of the effort experience than the subjective ratings. Specifically, zygomaticus activation in laboratory-based cognitive tasks may also reflect post-effort offset processes or weak and context-dependent hedonic signals, whereas subjective measures may more directly capture conscious effort valuation in those contexts.

Effort Experience as a Multi-Level Process

The present findings suggest that effort-related pleasure cannot be understood as a unitary or directly observable construct, but rather as a multi-level phenomenon emerging from interacting belief-based, contextual, and state-dependent processes. Across the preceding sections, a consistent pattern has emerged: subjective evaluations of effort showed systematic associations with motivational belief constructs and mood, whereas physiological pleasure-related signals remained weak or inconsistent. This dissociation indicates that different components of the experience of effort may be indexed by different methodological approaches.

At the most distal level, intelligence mindset reflects a broad meaning system concerning the interpretation of challenge and effort. More proximal constructs, such as effort enjoyment beliefs, directly target the affective valuation of exertion itself. In addition, contextual factors, including reward contingency and task meaning, determine whether effort becomes psychologically justified and thus potentially affectively valued. Finally, momentary mood states, themselves influenced by the task's demanding nature, further shaped how effort was experienced and evaluated in the given situation. Within this framework, physiological indices such as fEMG may capture only a narrow and context-dependent component of the effort experience, potentially reflecting brief valence responses or post-effort offset processes rather than the full appraisal-integrated valuation of effort. Subjective ratings, by contrast, likely reflect higher-order evaluative processes that integrate beliefs, contextual meaning, and current affective states, but are subject to biases like social desirability, retrospective reconstruction, and constricted by limited introspective access.

In the present study, the absence of intelligence mindset effects on fEMG measures does not imply that motivational beliefs are irrelevant to the paradigm of effort-related pleasure. Rather, it suggests that effort-related affect emerges from multiple interacting levels of processing, and that the translation from belief to physiological pleasure response may require specific contextual and motivational conditions that were only partially instantiated in the present laboratory design.

Limitations

Several limitations should be considered when interpreting the present findings. First, the physiological measures employed here may not have provided sufficiently sensitive indices of pleasure-related responding in the context of cognitive effort. As discussed above, facial EMG signals in laboratory effort paradigms appear to be context-dependent, and may reflect multiple processes beyond hedonic experience, including arousal, tension, or offset-related relief. Thus, the null effects observed for intelligence mindset on fEMG responses may partly reflect measurement constraints rather than the absence of motivational relevance per se.

Second, the experimental context itself may have limited the emergence of effort-related pleasure responses. The Math Effort Task represents a short-term, abstract laboratory paradigm in which effort is externally imposed and only weakly embedded in meaningful personal goals. Under low-meaning conditions, effort may be experienced primarily as cognitive strain rather than as a signal of growth or intrinsic reward, thereby attenuating both mindset-related and reward-related effects.

Third, the reward contingency manipulation was brief and largely implicit, which may have limited the depth of reward learning and, in turn, reduced the likelihood of detecting relevant effects on effort valuation.

Finally, the sample consisted primarily of psychology students participating in a university setting. This restricts the generalizability of the findings, as effort valuation and motivational beliefs may differ in other populations, such as adolescents, working adults, or individuals pursuing personally meaningful long-term goals. Moreover, participation may have been partly extrinsically motivated (e.g., course requirements), which could further reduce the subjective value of effort within the task context.

Altogether, these limitations highlight that the null psychological effects should be interpreted cautiously, as they may reflect both methodological constraints and the specific motivational characteristics of laboratory-based cognitive effort paradigms.

Future Directions

Future research should further refine the assessment of effort-related affect in motivational paradigms. A key priority concerns further validation of physiological measures such as the zygomaticus major as a marker of effort-related pleasure. While facial electromyography is widely used as a marker of positive affect, the present findings, together with prior work, suggest that its interpretation in cognitively demanding tasks may be more complex than commonly assumed (Devine et al., 2023). In particular, physiological signals observed after effort completion may partly reflect offset-related processes such as relief or affective contrast rather than intrinsic pleasure during effort engagement. Future studies should therefore further investigate the construct validity of zygomaticus fEMG activity in effort paradigms, including the possibility that these signals are sensitive to contextual factors such as task framing, reward contingency, or perceived control.

Closely related to this issue is the need to better understand the context-specificity of physiological indicators of effort-related affect. The present results suggest that physiological responses may depend strongly on the motivational meaning of the task and the perceived contingency between effort and outcomes. Systematic research comparing different task framings, reward structures, and levels of perceived effort-reward contingency may therefore help clarify under which conditions physiological measures capture effort-related pleasure versus other affective processes. More broadly, the present findings suggest that physiological indicators of effort-related pleasure may be most likely to emerge when effort is experienced as both meaningful and instrumentally linked to valued outcomes. Future studies could therefore directly test how perceived task meaning, effort-reward contingency, and perceived control interact in shaping affective responses to effort.

A second important direction concerns multimethod approaches to the study of effort valuation. Effort-related pleasure may be best captured by integrating multiple indicators, including subjective ratings, behavioral demand-seeking measures, and physiological markers such as cardiovascular indices or neural signals of motivational relevance. Combining these approaches may help disentangle the distinct components of effort experience and clarify how belief-based constructs such as intelligence mindset and effort enjoyment shape motivational engagement.

Finally, future research should examine effort-related pleasure in contexts with higher ecological validity. Laboratory paradigms may capture only a subset of effort experiences, particularly when effort is externally imposed and weakly embedded in meaningful goals. Growth mindset and related constructs may exert stronger influences in contexts where effort is connected to sustained learning, skill acquisition, or identity-relevant challenges. Investigating effort valuation in such real-world contexts may therefore provide a more comprehensive understanding of how motivational beliefs shape the affective experience of effort.

Conclusion

The present study examined whether intelligence mindset is associated with pleasure-related physiological responses during cognitive effort, and whether this associations depend on task difficulty or reward context. The confirmatory analyses provided no evidence that intelligence mindset predicts facial EMG indicators of pleasure during effort engagement. Thus, the hypothesized link between implicit intelligence beliefs and immediate physiological pleasure responses during cognitive effort was not supported in the present dataset.

At the same time, the exploratory findings suggest a more differentiated picture of effort-related affect. Subjective wanting and liking ratings varied systematically with task difficulty and were more strongly related to individual differences in effort enjoyment beliefs and momentary affective state than to intelligence mindset alone. In contrast to these findings, facial EMG indices showed little correspondence with these subjective evaluations.

Taken together, these findings highlight the importance of considering different levels of analysis when studying the affective experience of cognitive effort. Overall, the present findings suggest that the affective experience of cognitive effort is not a unitary physiological response but a multi-level process in which motivational beliefs, contextual meaning, and momentary affective states jointly shape how effort is appraised and experienced.

Use of AI Tools

Generative AI tools were used in a limited and supportive manner during the preparation of this thesis. ChatGPT (OpenAI) was used as a discussion and reflection aid during the writing process, including assistance with structuring arguments and improving language clarity.

The AI-based literature discovery tool Elicit was occasionally used to gain an overview of research topics and identify potentially relevant publications. All sources cited in this thesis were independently checked and verified by the author.

Zotero was used as reference management software to organize and format citations and the bibliography.

Deepl was used selectively for language support and translation of individual phrases during the writing process.

All analyses, interpretations, and final formulations were independently developed and critically reviewed by the author.

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Appendix

Abstract

Effort is often conceptualized as an aversive cost that individuals seek to minimize. However, recent research suggests that effort can also be experienced as meaningful or even rewarding under certain conditions. Within the framework of implicit theories of intelligence, individuals differ in their beliefs about the malleability of ability, shaping how effort is interpreted. Whereas growth-oriented beliefs frame effort as a signal of learning and development, fixed-oriented beliefs may frame effort as a sign of limited ability. The present study examined whether intelligence mindset is associated with pleasure-related responses to cognitive effort and whether these responses depend on task difficulty and reward context. A sample of 194 university students completed an incentivized N-back task in which rewards were contingent on either effort or performance, followed by a non-incentivized Math Effort Task. During the latter, anticipatory and post-effort affective responses (wanting and liking) were assessed using trial-level self-reports and facial electromyography of the zygomaticus major muscle. Intelligence mindset was measured prior to the experiment and included as a continuous predictor. Confirmatory analyses provided no evidence that intelligence mindset predicted physiological pleasure-related responses, nor that task difficulty or reward condition moderated these associations. Exploratory analyses showed that subjective ratings decreased with increasing task difficulty, were positively related to intelligence mindset and effort enjoyment beliefs and were negatively related to baseline fatigue. Subjective and physiological measures showed little correspondence, highlighting the value of integrating multiple levels of analysis to understand how cognitive effort is experienced.

Deutsche Zusammenfassung

Kognitive Anstrengung wird in vielen theoretischen Ansätzen als aversiver Kostenfaktor betrachtet, den Menschen möglichst vermeiden. Neuere Forschung legt jedoch nahe, dass Anstrengung unter bestimmten Bedingungen auch als bedeutsam oder sogar als belohnend erlebt werden kann. Im Rahmen der impliziten Intelligenztheorien unterscheiden sich Menschen darin, ob sie Fähigkeiten als veränderbar oder als stabil ansehen. Diese Überzeugungen beeinflussen, welche Bedeutung Anstrengung erhält. Die vorliegende Studie untersuchte daher, ob individuelle Unterschiede in Intelligenz-Mindsets mit affektiven Reaktionen auf kognitive Anstrengung zusammenhängen und ob diese Zusammenhänge von Aufgabenschwierigkeit und Belohnungskontext beeinflusst werden. Insgesamt nahmen 194 Studierende an einem Laborexperiment mit zwei kognitiven Aufgaben teil. Zunächst bearbeiteten die Teilnehmenden den N-Back-Task mit monetären Belohnungen, bei dem die Belohnung entweder an Anstrengung oder an Leistung gekoppelt war. Anschließend absolvierten sie den Math Effort Task ohne monetäre Belohnung. Während dieser Aufgabe wurden antizipatorische (Wanting) und konsummatorische (Liking) affektive Reaktionen mittels Selbstberichte und facialer Elektromyographie des *Musculus zygomaticus major* erfasst. Das Intelligenz-Mindset wurde vor dem Experiment erhoben und als kontinuierliche Individualdifferenzvariable berücksichtigt. Die konfirmatorischen Analysen zeigten keine Hinweise darauf, dass Intelligenz-Mindset physiologische affektive Reaktionen vorhersagt oder dass Aufgabenschwierigkeit beziehungsweise Belohnungsbedingung diese Zusammenhänge moderieren. Explorative Analysen zeigten jedoch, dass selbstberichtetes Wanting und Liking mit steigender Aufgabenschwierigkeit abnahmen, positiv mit Intelligenz-Mindset und Effort-Enjoyment-Überzeugungen zusammenhingen und negativ mit Müdigkeit assoziiert waren. Zudem zeigte sich nur eine geringe Übereinstimmung zwischen subjektiven Bewertungen und physiologischen Maßen. Die Ergebnisse unterstreichen die Bedeutung multimethodaler Ansätze, um besser zu verstehen, wie kognitive Anstrengung erlebt und bewertet wird.