Planning to Save Energy: How Information Format Affects Accuracy

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Abstract

Effective communication of energy consumption information is crucial for promoting residential energy conservation. This research, encompassing two experiments, investigated the influence of presenting energy-saving targets as absolute units (kilowatt-hours, kWh), percentages, or derived monetary values (U.S. dollars) on the precision of conservation plans. Participants completed a simulated household planning task, allocating energy usage reductions across various appliances to meet a specified goal format. Convergent results across experiments indicated that framing reduction goals in absolute kWh units yielded significantly greater planning accuracy compared to both percentage-based and monetary formats. Additionally, higher energy literacy consistently correlated with enhanced planning precision irrespective of format. These findings suggest that utilizing absolute units like kWh is more efficacious for communicating energy-saving goals intended to support detailed planning, while also underscoring the potential utility of interventions aimed at improving consumer energy literacy.

Keywords: energy literacy, information format, planning accuracy, decision making

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Introduction

Energy insecurity has emerged as a critical public health concern, especially among low-income households, who frequently face difficult choices between paying energy bills and meeting other essential needs (Bednar & Reames, 2020; Memmott et al., 2021). Such households often experience unsafe coping strategies (e.g., foregoing heating during winter months), which disproportionately burden at-risk populations and heighten risks of utility disconnection (Memmott et al., 2021). Moreover, residential energy use contributes to climate change, intensifying the urgency for sustainable solutions (Farghali et al., 2023).

Given the relevance of promoting behavior change to reduce energy consumption, numerous research efforts have focused on identifying determinants of energy behavior and designing interventions to effectively reduce consumption. Interventions providing tailored energy use information and feedback, often coupled with specific energy-saving goals, have shown promise in achieving measurable reductions in consumption and improving related knowledge, as exemplified by findings from Abrahamse et al. (2007) where households receiving such interventions decreased direct energy use significantly more than controls.

However, the success of such interventions may hinge on how effectively energy information is communicated, with format and presentation context significantly influencing understanding and action (Canfield et al., 2017; Fischer, 2008). Consequently, the present study investigates whether presenting energy reduction goals in different numerical representations (e.g., absolute units vs. relative percentages vs. monetary values) systematically influences the accuracy with which consumers can develop corresponding conservation plans.

Representation Formats

Although many residents voice concern about energy use, their factual understanding and day-to-day behaviors often lag behind that concern, a misalignment documented by DeWaters and Powers (2011). This knowledge-action gap highlights the practical need to present utility information in ways that help consumers convert abstract goals into concrete plans. Addressing

the role of information presentation in this context, Canfield et al. (2017) presented participants with hypothetical electricity bills containing various data (e.g., historical usage, neighbor comparisons, appliance breakdowns) across different formats (tables, bar graphs, icon graphs). Their results showed that tables tended to be the most comprehensible format for evaluating energy use information, and that historical electricity use details prompted the highest intentions for energy savings, irrespective of format. Furthermore, Canfield et al. (2017) found that higher energy literacy consistently correlated with better understanding of energy-related information across all representation types.

Although many individuals express a desire to conserve energy, research consistently shows that abstract goals (e.g., "reduce overall usage by 15%") often fail to translate into effective behavior change unless accompanied by specific, actionable steps (Abrahamse et al., 2005; Nemati & Penn, 2020). For instance, Abrahamse et al. (2005) demonstrated that merely providing general information about energy savings rarely alters consumption patterns unless consumers also receive concrete instructions or tailored feedback.

Similarly, Tonke (2024) reported that sending households brief but precise text messages outlining how to reduce water use (e.g., limiting irrigation times, adjusting washing machine settings) yielded meaningful decreases in consumption, underscoring the importance of procedural knowledge, namely, knowing how to operationalize a goal rather than simply why it is desirable. In the context of energy conservation, this implies that interventions should not only highlight potential reductions (such as a 15% target) but also guide residents in allocating those reductions across specific appliances or behaviors (Attari et al., 2010). Additionally, meta-analytic findings suggest that people respond more robustly to household-level feedback that situates their usage within a personalized framework, thereby reducing the cognitive burden of determining next steps (Nemati & Penn, 2020).

How information is numerically framed shapes comprehension and subsequent choices. Of particular relevance are reference class effects, which occur when numerical statements are presented without a clear or intuitive basis for comparison, making it difficult to infer meaningful

quantities (Gigerenzer & Edwards, 2003; Reimer et al., 2015). A large body of prior research suggests that presenting data in terms of absolute counts or frequencies, as opposed to probabilities or percentages, can promote more accurate comprehension and facilitate decision making. However, it is important to note that even intuitive formats can pose challenges. For instance, Weber et al. (2018) found that individuals often struggle with reasoning tasks presented in natural frequencies because they inadvertently revert to more complex probabilistic thinking.

Unit selection and display format can also influence energy decisions. For instance, tables are generally more effective than graphs for conveying specific electricity usage data because they facilitate straightforward point reading (Canfield et al., 2017). Furthermore, the framing of energy costs, such as displaying monthly rather than daily or yearly expenses, can significantly affect consumers' choices (Gill et al., 2022). Because kilowatt-hours (kWh) constitute a linear, appliance-level metric, they can streamline arithmetic and facilitate cross-appliance comparison. In contrast, many consumers have a preference for receiving energy feedback in terms of monetary values over scientific units (Karjalainen, 2011; Nemati & Penn, 2020), as well as better long-term appliance selection with information presented in monetary terms (Blasch et al., 2019). However, it remains uncertain how these reported benefits might generalize to the more complex task of household energy planning, where usage patterns are multifaceted and subject to a variety of contextual influences.

Overview of Current Research

While prior studies have examined communication strategies and format effects related to energy use, the specific question of how different numerical representations impact consumers' ability to formulate precise energy conservation plans remains largely unexplored. A particular gap exists in understanding whether presenting energy-saving goals using absolute units (kWh), relative percentages, or derived monetary values (USD) influences the accuracy of planning appliance-specific reductions. The present research directly confronts this issue, investigating how these distinct information formats (kWh, percentage, and USD) affect the accuracy of energy-planning decisions. Through manipulation of the presentation format, this study seeks to

clarify the relationship between representational choices and planning precision. Drawing upon the reviewed literature, we hypothesized that: 1) Presenting energy reduction goals in absolute units (kWh) will lead to greater planning accuracy compared to percentage-based or monetary formats, as absolute units provide a more direct and less ambiguous representation of energy quantities. 2) Higher energy literacy will be associated with more accurate planning, as individuals with greater energy knowledge may be better equipped to process and utilize the provided information, regardless of format. We also examined the potential of several exploratory variables, such as goal difficulty and the rounding of numerical values, to further elucidate the factors that influence planning accuracy.

Experiment 1

See Figure 1 for an example of a planning trial as it was seen by participants.

Methods

Participants

We implemented our task and surveys on Qualtrics, and recruited participants through Amazon Mechanical Turk. In Experiment 1, 235 participants were initially recruited. Data from six participants were excluded due to unusually large error magnitudes (error magnitudes exceeding 2.5 standard deviations from the group mean), resulting in a final sample of 229 participants (136 males, 92 females, 1 participant not specified). The average age of participants was 34.3 years (SD = 10.2). Most participants (76%) reported using a calculator to complete the task.

Materials and Design

The study employed a mixed design with reference class (kWh, percentage, USD) as a between-subjects factor and state/family scenario as a within-subjects factor. Each participant completed energy reduction planning tasks for two different states (i.e., family scenarios), with state order counterbalanced across participants. The family scenarios themselves depicted four households situated in different climate regions: Texas (Smith family) and California (Adams

family), chosen as exemplars of warmer climates, and Colorado (Wells family) and Massachusetts (Davis family), selected to represent colder climates. Importantly, the state-average energy consumption figures presented alongside each family's specific usage data were carefully constructed based upon information sourced from U.S. Energy Information Administration (EIA) surveys; this approach was adopted specifically to ensure the inclusion of comparative data reflecting a diverse range of climatic conditions, encompassing both typically hotter and colder states. Participants also completed an 8-item questionnaire assessing their knowledge of energy consumption and conversion (DeWaters & Powers, 2011), and a question indicating whether they used a calculator for the task.

Procedure

Participants were provided with energy usage data for two hypothetical families and tasked with creating action plans to meet specified energy reduction goals. Participants were informed at the start of the study that they would be presented with tables of detailed energy usage data for each family, and that they would have to create two action plans for each of the families. Each action plan goal was implemented by allocating usage across five appliance categories: heating, cooling, water heating, refrigerator, and other appliances (e.g., TV, lighting, washer/dryer). For each family scenario, participants were shown a table containing the family's utility usage from the prior year, alongside the state averages for each appliance category (see Figure 1). For each scenario, participants were asked to create two possible action plans to achieve the target reduction in total household energy usage . Depending on their reference class condition, the target reduction amount was presented either in kilowatt-hours (kWh), as a percentage of total household usage, or in U.S. dollars. In all conditions, the target reduction was equivalent to a 15% reduction in total household kWh. For example, participants assigned to the Wells family scenario (Colorado), as depicted in Figure 1, were asked to achieve a reduction of 5,965 kWh in the kWh condition, 15% in the Percentage condition, or $656 in the USD condition, all representing the same underlying 15% energy reduction target for that specific household.

Figure 1

Example energy planning task trial

The Wells family wants to reduce its household electricity use by 15% next year.
Please complete two possible action plans that will help the Wells family achieve this goal. Please enter how many kWh should be used next year by each appliance and the total kWh each plan would use. **Enter only whole numbers.** Try to provide close estimations. You may use a calculator to complete the task.

Note: The Wells family used 9,233 more kWh than the average household in Colorado last year.

	Electricity Used Last Year by the Wells Family (kWh)	Average Electricity Used Last Year by Households in Colorado (kWh)	**Action Plan 1**	**Action Plan 2**
Cooling (Central A/C)	697	498		
Heating the Home	18,052	16,411		
Water Heating	11,667	5,832		
Refrigerator	1,370	1,142		
Other (Television, Lighting, Electronics, Washer/Dryer, etc.)	7,982	6,652		
Total kWh	39,768	30,535		

Note. Participants saw a table with a family's previous year electricity usage (here for the Wells family in Colorado) and were asked to allocate energy usage to meet a 15% reduction goal. The format of the reduction goal was manipulated to be either a percentage (15% reduction), kilowatt hours (5965 kWh), or USD ($656). Participants in the USD condition were provided with the conversion rate between kWh and USD. All participants completed two scenarios, and for each scenario, they proposed two distinct action plans

Results

All preprocessing and analyses were carried out in `R` version 4.4.3 (Team, 2020) and the Tidyverse package (Wickham et al., 2019). Mixed Bayesian regressions were fit using the `brms` package (Bürkner, 2017), with participants and family scenario set as random effects.

Table 1

Study 1: Summary of planning accuracy by reference class

Reference Class	N	Exact Match Rate(%)	Close Match Rate(%)	Abs. Deviation	Log Abs. Deviation
kWh	76	38 (45)	54 (45)	0.029 (0.117)	-3.69 (2.79)
Percentage	67	22 (37)	40 (41)	0.056 (0.104)	-3.10 (1.87)
USD	86	10 (28)	22 (33)	0.095 (0.094)	-2.40 (1.09)

Note. Summary statistics by reference class condition, based on participant-level averages. Exact Match Rate and Close Match Rate represent the mean percentage of trials (per participant) where the proposed reduction exactly matched or closely matched (±2% tolerance) the target goal (standard deviations in parentheses), respectively. Abs. Deviation and Log Abs. Deviation reflect the median (IQR in parentheses) of each participant's absolute deviation from the target goal.

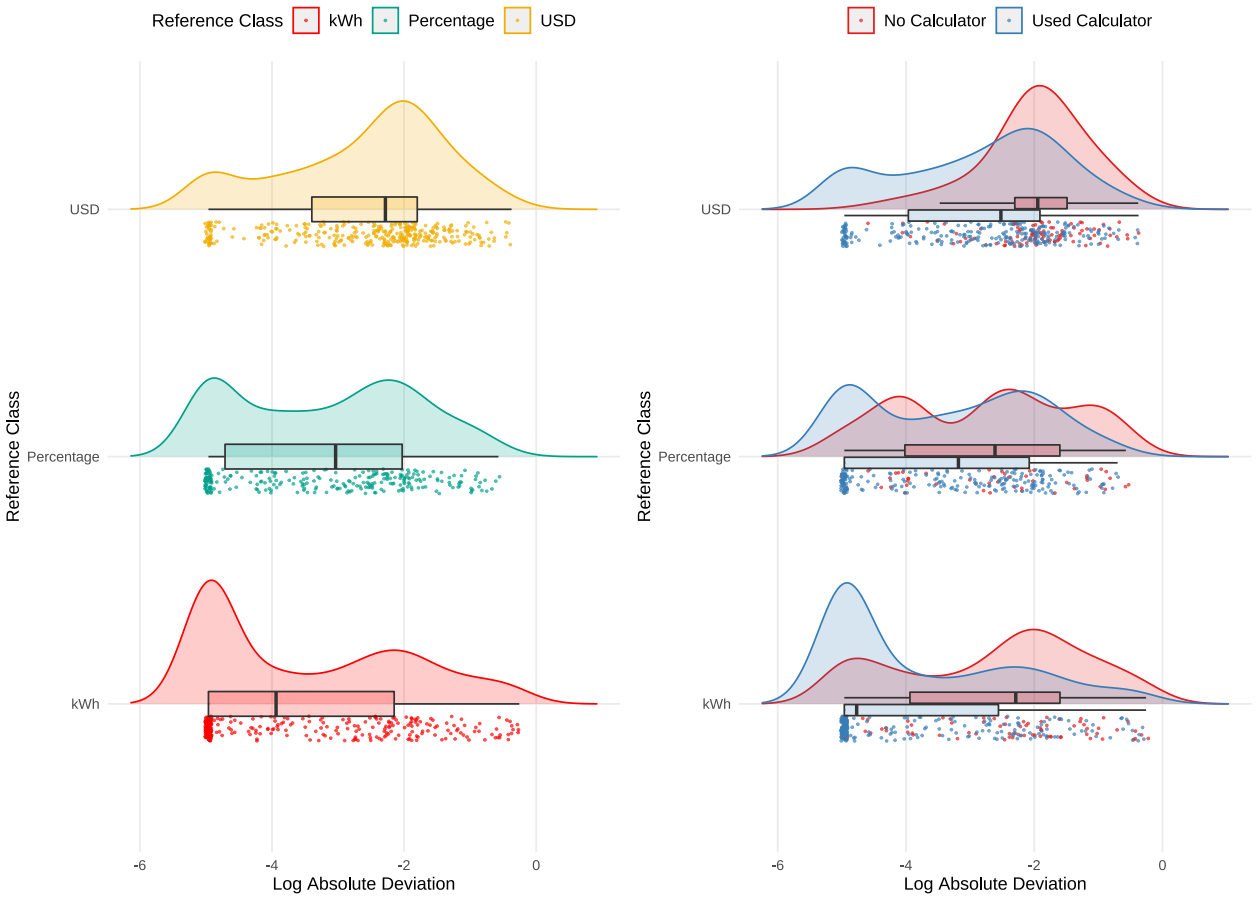
The summary statistics in Table 1 suggest descriptive differences in planning accuracy across reference class conditions, with the kWh condition yielding the highest rates of exact matches, and lowest absolute deviations from the target reduction goal. However, use of these performance metrics to compare conditions is complicated by the non-normality of their distributions. Specifically, the substantial standard deviations associated with the match rates in Table 1, coupled with the visual evidence presented in Figure 2, highlight the skewed, and potentially bimodal distribution of the underlying planning errors.

In light of these distributional characteristics, we elected to bin planning performance into ordered accuracy levels (as shown in Table 3). Consequently, we binned individual trial outcomes into three distinct, ordered categories: "Exact match" (0% absolute error), "0.01-5% error" (minor deviations), and "Over 5% error" (larger deviations). This binned `accuracy_level`

variable subsequently served as the dependent measure in our primary inferential analyses examining the impact of reference class on planning accuracy

Figure 2

Experiment 1: Planning Error Distributions



Note. Distribution of the log of the absolute error between the participant's action plan and the reduction goal. Left side plot separates across different reference class conditions (kWh, Percentage, USD). Right side plot separates by self-reported calculator use. A lower log absolute error suggests higher planning accuracy.

Table 3

Experiment 1: Categorization of Participants according to Accuracy Levels

Accuracy Level	kWh	Percentage	USD
Exact match	38.5%	22.4%	10.2%
0.01-5% error	22.7%	29.5%	25%
Over 5% error	38.8%	48.1%	64.8%

Note. The table shows the percentage of action-plans which fell into each accuracy level for each reference class condition (percentages of kWh, $, and USD columns reflect within condition percentages).

Group comparisons were conducted with Bayesian ordinal regression (Bürkner & Vuorre, 2019; Kruschke, 2014). We modeled the ordered accuracy outcome as a function of the reference class condition, while controlling for random variation across participants and family scenarios (Equation 1).

$$\text{Accuracy Level} \sim \text{Reference Class} + \text{Calculator} + (1|\text{id}) + (1|\text{Family Scenario}) \quad (1)$$

This approach allows the estimation of threshold parameters and regression coefficients that characterize how changes in predictor variables (such as the reference class: kWh, percentage, or USD) relate to probabilities of being in each accuracy category. We used a cumulative logit link function to model the ordered accuracy outcome, and we specified weakly informative priors (Kruschke, 2014) for the regression coefficients (normal distributions with mean 0 and standard deviation of 1) and for the cutpoints (normal distributions with a mean of zero and a standard deviation of 4.0). The approach can be used to estimate threshold parameters and regression coefficients that characterize how changes in predictor variables (such as the reference class: kWh, percentage, or USD) relate to probabilities of being in each level of accuracy (0% absolute error; 0.01-5% error; Over 5% error). Bayesian regression provides a probability distribution over the plausible values of the model parameters, allowing for a

probabilistic interpretation of the uncertainty associated with these estimates. The width of the credible intervals (Bayesian equivalent of confidence intervals) derived from the posterior distribution directly indicates the degree of uncertainty in these effects.

Table 5

***Experiment 1**: Ordinal Regression Results of a Test of Differences between conditions in Accuracy Levels*

Parameter	Estimate	CI_Lower	CI_Upper	pd
Intercept[1]	-4.21	-5.90	-2.58	1.00
Intercept[2]	-0.89	-2.49	0.71	0.87
RefClass-Percentage	1.44	0.07	2.88	0.98
RefClass-USD	3.13	1.81	4.50	1.00
calc-UsedCalculator	-3.30	-4.80	-1.92	1.00

Note. Ordinal regression results. Positive coefficient estimates for the reference class predictors indicate that those conditions are associated with higher error categories relative to the kWh baseline.

Table 7

***Experiment 1**: Odds ratios for group comparisons*

Comparison	odds_ratio	CI_Lower	CI_Upper
Percentage vs kWh	4.2	1.1	18
USD vs kWh	22.9	6.1	90

Note. Odds ratios greater than 1 indicate increased odds of falling into a worse accuracy category compared to the kWh condition

As shown in Table 5, the reference class coefficients are positive for both the Percentage (Estimate = 1.44, 95% CI: 0.07 to 2.88, pd = 0.98) and USD (Estimate = 3.13, 95% CI: 1.81 to 4.50, pd = 1.00) conditions, relative to the kWh baseline. This indicates that, compared to the kWh condition, participants in both the Percentage and USD conditions were more likely to

produce plans that fell into higher error categories. Moreover, the odds ratios (see Table 7) suggest that the USD condition led to a notably higher likelihood of large errors compared to the kWh baseline (OR = 22.9), while the Percentage condition also demonstrated increased odds (OR = 4.2) but was somewhat less detrimental to accuracy than USD. These results align with our descriptive findings and further clarify that framing the target reductions in absolute kWh units may facilitate significantly more accurate planning. To evaluate the descriptive adequacy of our statistical model, we performed posterior predictive checks, a standard Bayesian technique wherein data simulated from the fitted ordinal model are compared against the observed data. As shown in Figure 3, which compares the observed proportions of participant responses for each accuracy level (represented by bars) to the models predicted proportions (represented by points). The close correspondence between the observed bars and predicted points across different accuracy levels and reference class conditions suggests that the model adequately captures the patterns in the observed data.

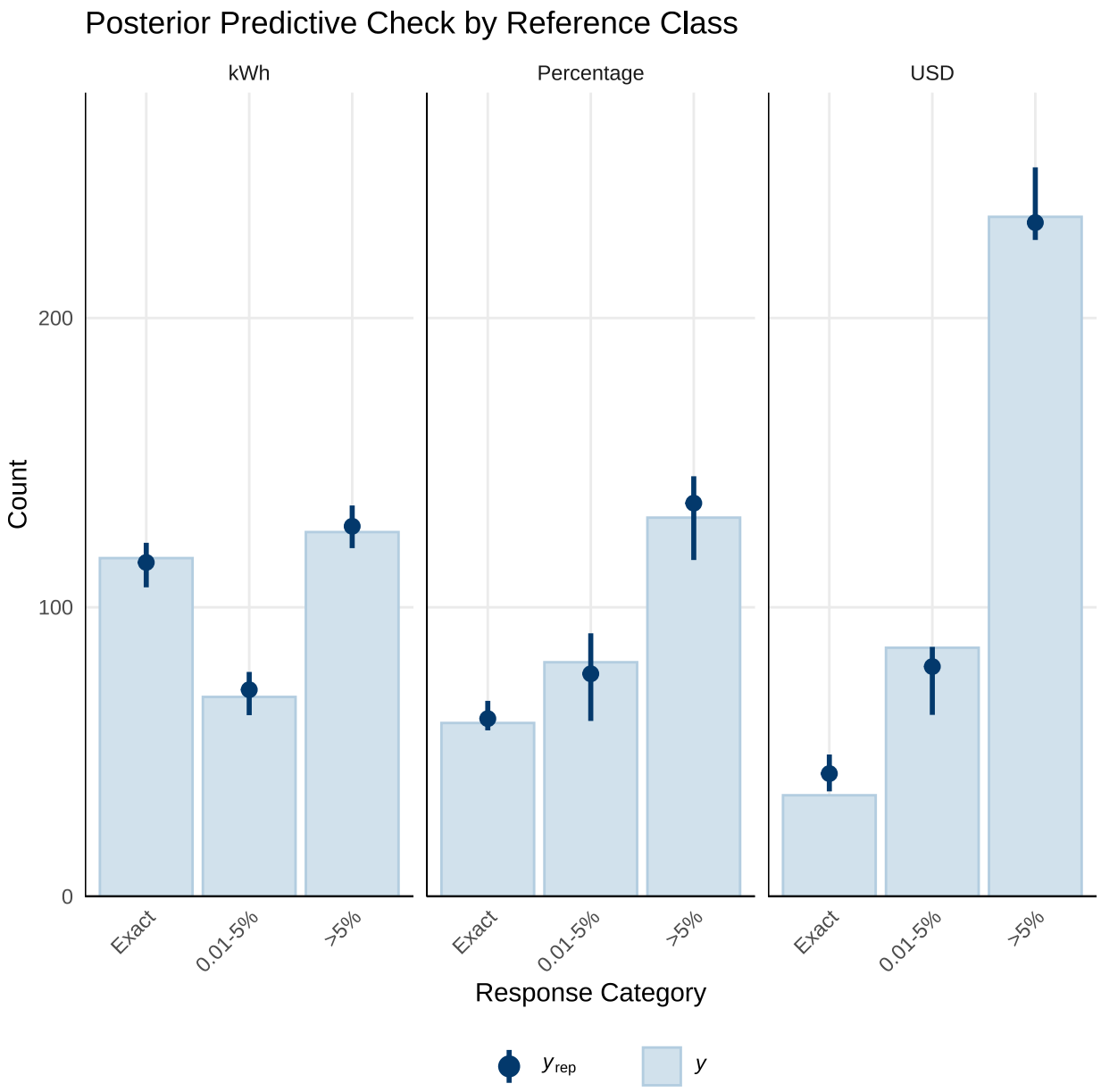
To further investigate individual factors that may influence planning accuracy, we examined the relationship between participants' energy literacy scores and their performance on the task. A Bayesian linear regression model was fit with log-transformed absolute error as the outcome variable and energy literacy score as the predictor, controlling for random effects of participant and state. Results indicated a significant negative relationship between energy literacy and log absolute error (Estimate = -2.35, 95% CI: -2.88 to -1.81), suggesting that participants with higher energy literacy scores tended to have smaller deviations from the target reduction goal, and thus more accurate plans overall (Figure 4).

Experiment 1: Discussion

Experiment 1 examined how different numerical representations of energy reduction goals affected participants' planning accuracy. In line with our hypothesis that absolute units would yield better accuracy, the kWh condition supported significantly more precise energy reduction plans than either the Percentage or USD conditions. Although the Percentage format was detrimental to accuracy relative to kWh, it was the USD condition that consistently produced the

Figure 3

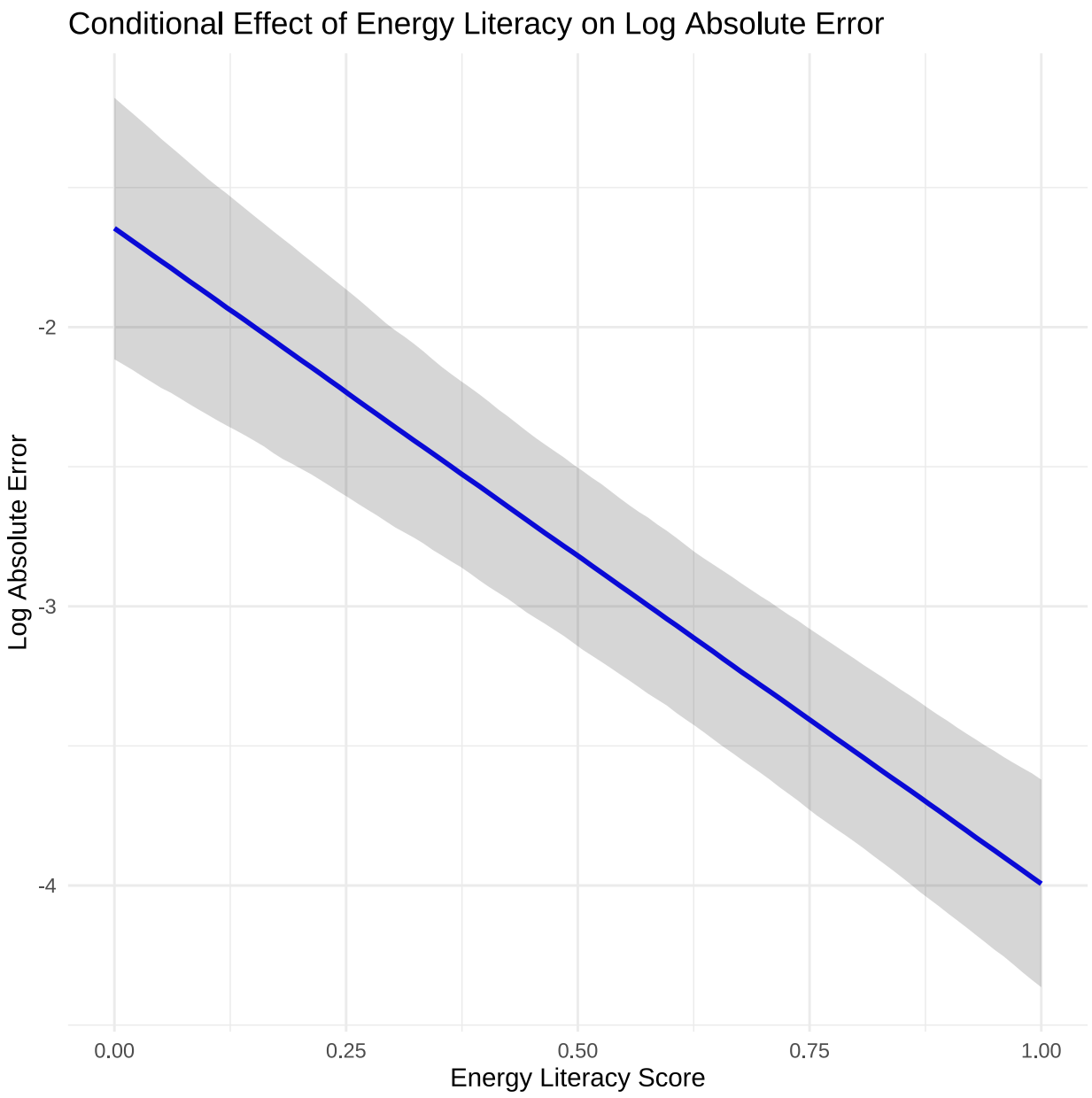
Experiment 1: Posterior Predictive Check



Note. Posterior predictive check for the Bayesian ordinal regression model. Blue bars show the observed frequencies for each accuracy level (Exact match, 0.01-5% error, and Over 5% error), dots with error bars represent the model predictions. The plot is faceted by reference class condition (kWh, Percentage, USD).

Figure 4

Experiment 1. Conditional effect of energy literacy on log absolute error



Note. The plot shows the relationship between energy literacy score and log absolute error, controlling for random effects of participant and state. Higher energy literacy scores are associated with smaller deviations from the target reduction goal, indicating more accurate planning.

poorest outcomes, suggesting that monetary terms, while intuitive in everyday contexts, may not serve as effective reference classes for planning appliance-specific reductions in energy use.

Experiment 2 will extend these findings by examining whether additional variables, such as the difficulty of the reduction goal or the rounding of numerical values, further interact with reference class conditions, thereby providing a more comprehensive understanding of how to optimize energy information presentation for improved planning accuracy.

Experiment 2

Introduction

Building upon the preliminary evidence from Experiment 1, which indicated that representing energy reduction targets in absolute kilowatt-hour (kWh) units might yield superior planning accuracy relative to percentage or monetary formats, Experiment 2 was designed to further probe the robustness and nuances of this effect. A primary objective was to replicate the core finding regarding the influence of reference class on planning precision. Additionally, this second experiment sought to broaden the investigation by examining the potential impact of other task parameters; specifically, we manipulated the difficulty of the reduction goal (comparing a 10% versus a 15% target) and the granularity of the presented numerical usage data (using exact versus rounded figures).

Methods

In Experiment 2, 196 participants were recruited from Amazon Mechanical Turk, and six were excluded because their error magnitudes were statistical outliers (error magnitudes exceeding 2.5 standard deviations from the group mean), leaving a final sample of 190 participants (102 males, 88 females, with an average age = 35.5, SD=9.5)

Experiment 2 employed a mixed experimental design with reference class (USD, Percentage, kWh) as a between-subjects factor, and two within-subjects factors: task goal (10% vs. 15% reduction) and the presentation of last year's usage data (exact vs. rounded numbers). The order of presentation of the goal, rounding, and family scenarios was counterbalanced across participants. As in Experiment 1, each participant completed the energy reduction planning task

for two different family-state scenarios. In the "rounded" condition, both the family's previous year usage and the state averages were rounded to the nearest whole number.

Results

Table 9

Experiment 2: Summary of planning accuracy by reference class

Reference Class	N	Exact Match Rate(%)	Close Match Rate(%)	Abs. Deviation	Log Abs. Deviation
kWh	68	44 (45)	52 (46)	0.022 (0.182)	-3.87 (3.12)
Percentage	67	28 (36)	42 (42)	0.062 (0.138)	-3.22 (2.31)
USD	55	20 (38)	29 (40)	0.102 (0.135)	-2.42 (1.52)

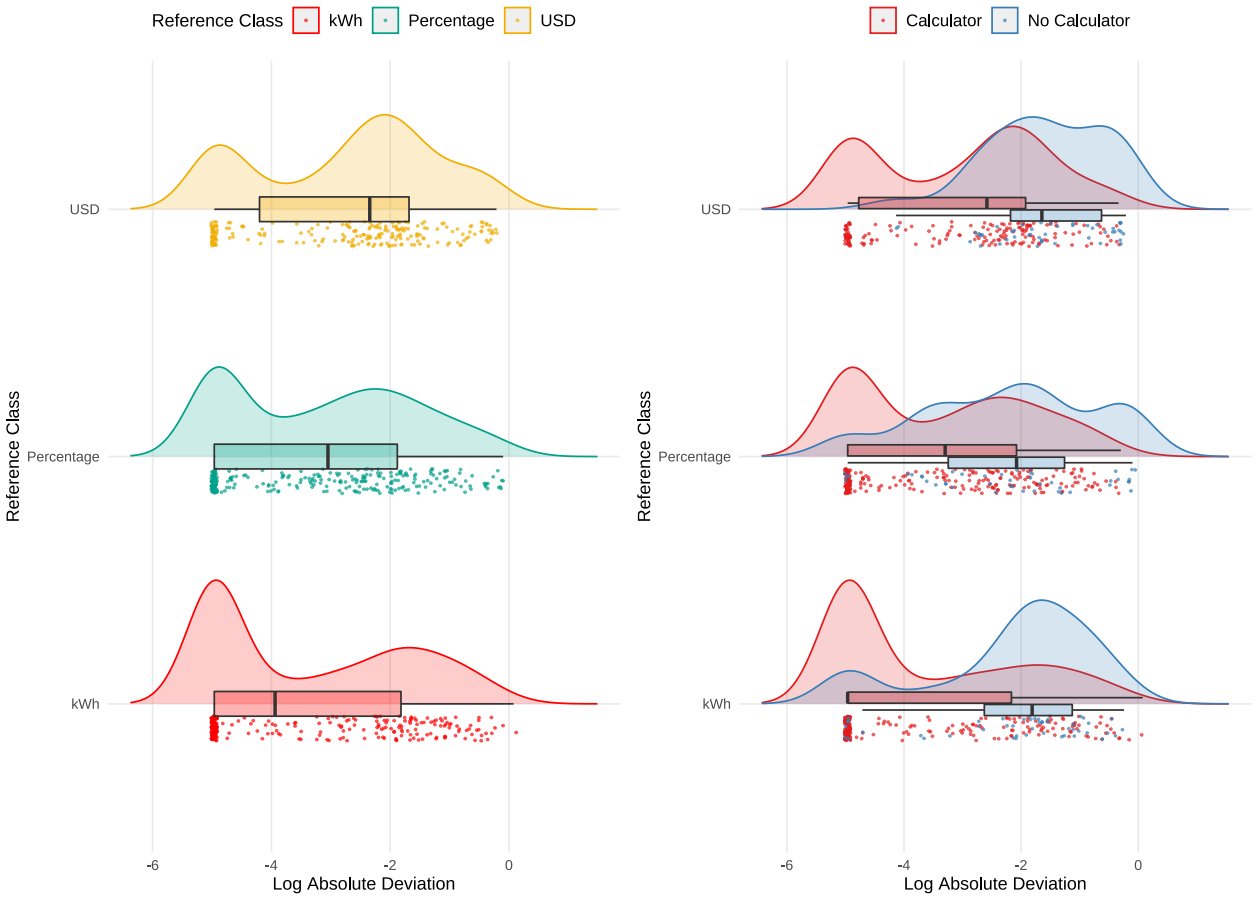
Note. Summary statistics by reference class condition, based on participant-level averages. Exact Match Rate and Close Match Rate represent the mean percentage of trials (per participant) where the proposed reduction exactly matched or closely matched (±2% tolerance) the target goal (standard deviations in parentheses), respectively. Abs. Deviation and Log Abs. Deviation reflect the median (IQR in parentheses) of each participant's absolute deviation from the target goal.

As in Experiment 1, accuracy was categorized into three ordinal levels: "Exact match" (0% error), "0.01-5% error," and "Over 5% error". The analyses for Experiment 2 employed a Bayesian ordinal regression model to examine the probability of falling into one of three accuracy categories (exact match, minor deviations, or substantial deviations) as a function of the reference class condition (kWh, Percentage, USD), while including pct_goal (10% vs. 15%), rounded (exact vs. rounded usage data), and calculator usage as additional predictors. Random intercepts were specified for both participant and state (Equation 2). The model was fit using the brms package in R, with weakly informative priors for the regression coefficients and cutpoints (Kruschke, 2014).

$$\text{Accuracy} \sim \text{Reference Class} + \text{Calculator} + \text{Goal} + \text{Rounded} + (1|\text{id}) + (1|\text{Family Scenario}) \quad (2)$$

Figure 5

Experiment 2: Planning Error Distributions



Note. Distribution of the log of the absolute error between the participant's action plan and the reduction goal. Left side plot separates across different reference class conditions (kWh, Percentage, USD). Right side plot separates by self-reported calculator use. A lower log absolute error suggests higher planning accuracy.

Table 11

Experiment 2. *Parameter estimates from the ordinal regression model*

Parameter	Estimate	CI_Lower	CI_Upper	pd
Intercept[1]	-1.45	-2.85	-0.07	0.98
Intercept[2]	1.26	-0.09	2.65	0.97
RefClass-Percentage	1.02	-0.63	2.71	0.89
RefClass-USD	2.27	0.53	3.98	0.99
calc-NoCalculator	4.10	2.20	6.06	1.00
pct_goal15%	-0.39	-0.81	0.04	0.96
rounded-Rounded	-0.53	-0.96	-0.11	0.99

Note. Ordinal regression results. Positive coefficients for the reference class predictors indicate that those conditions are associated with higher error categories relative to the kWh baseline. Coefficients for calc are in reference to the 'Used Calculator' group, coefficient for the pct_goal is in reference to the 10% goal, and coefficient for rounded is in reference to the 'Not Rounded' group.

See Table 9 for a breakdown of the descriptive statistics, and Figure 5 for visualizations of the full error distributions. The ordinal regression analysis (see Table 11) revealed that the USD reference class significantly increased the odds of higher error categories compared to the kWh reference class (OR = 9.68, 95% CI: [1.69, 53.4]). Participants in the USD condition were therefore substantially more likely to deviate from the target energy reduction goal compared to those in the kWh condition. In contrast, the Percentage condition's odds ratio relative to kWh was more uncertain (OR = 2.78, 95% CI: [0.53, 15.0]), indicating that although there may be a trend toward reduced accuracy in the Percentage condition, the evidence was not definitive (Table 13). Posterior predictive checks are shown in Figure 7.

We also found that using rounded numbers modestly improved accuracy (Estimate = -0.53, 95% CI: [-0.96, -0.11]), with participants having 0.59 times the odds of falling into a worse accuracy category when working with rounded values. The more challenging 15% reduction goal

Table 13

Experiment 2. *Odds ratios for group comparisons*

comparison	odds_ratio	CI_Lower	CI_Upper
Percentage vs kWh	2.78	0.53	15.0
USD vs kWh	9.68	1.69	53.4
calc-NoCalculator	60.37	9.02	426.4
15% Goal vs 10% Goal	0.68	0.44	1.0
Rounded vs Not	0.59	0.38	0.9

Note. Odds ratios greater than 1 indicate increased odds of falling into a worse accuracy category compared to the kWh condition

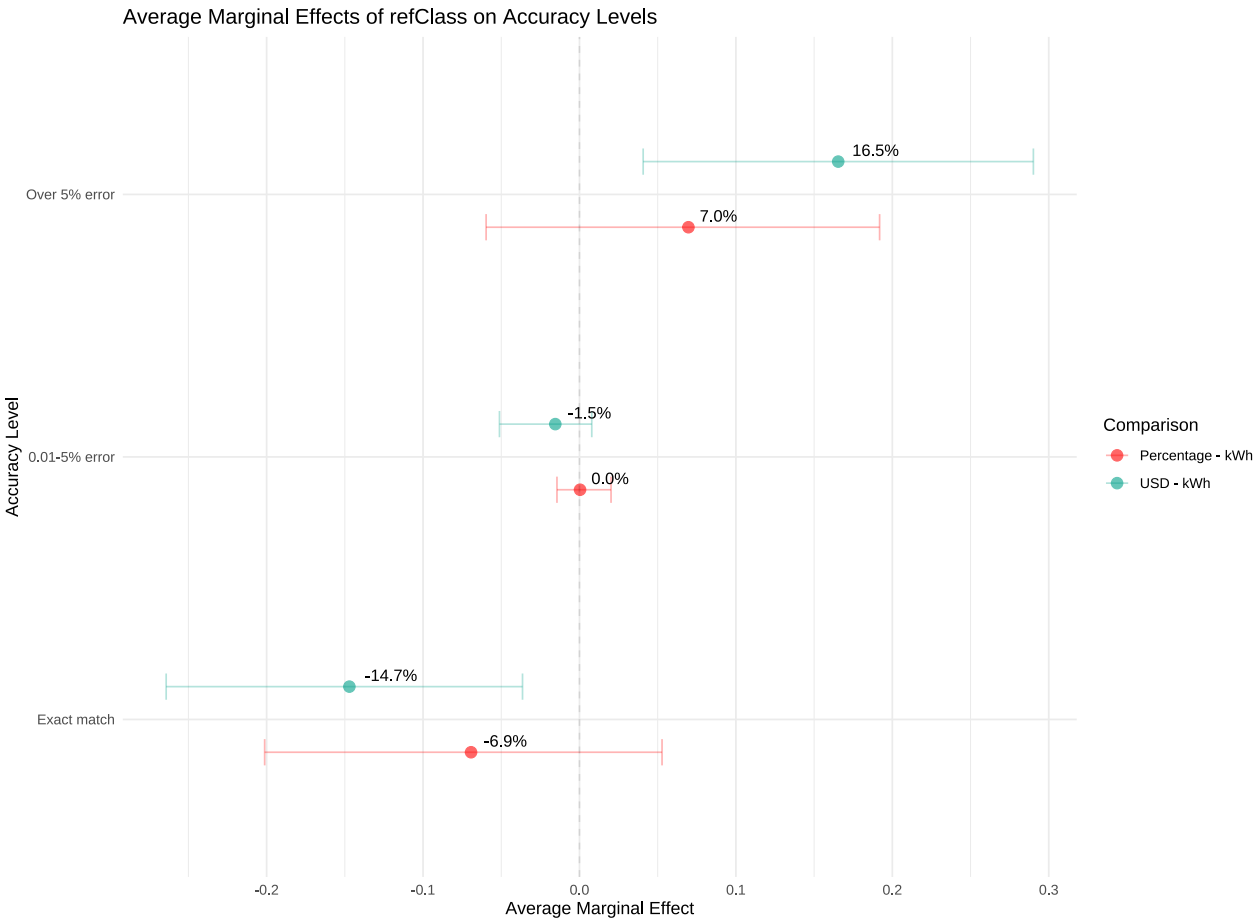
was associated with slightly better performance compared to the 10% goal, Estimate = -0.39, 95% CI: [-0.81, 0.04], though this effect was relatively small. Consistent with Experiment 1, the use of a calculator had a large and significant effect on accuracy. The coefficient for calc-NoCalculator was Estimate = 4.10 95% CI: [2.20, 6.06], and the corresponding odds ratio was 60.37 (95% CI: [9.02, 426.4]), indicating that participants who did not use a calculator were substantially more likely to fall into higher error categories.

Figure 6 shows the marginal effects of Reference Class on each level of accuracy_level. These results reveal that switching from kWh to Percentage decreased the probability of an "Exact match" by an average of 7.0 percentage points, 95% CI: [-19.2, 4.2] and increased the probability of falling into the "Over 5% error" category by 6.9 percentage points, 95% CI: [-4.5, 18.6]. Similarly, switching from kWh to USD decreased the probability of an "Exact match" by 15 percentage points, 95% CI: [-26.7, -3.3], and increased the probability of "Over 5% error" by 16.5 percentage points, 95% CI: [3.7, 29.3].

We once again examined the effect of energy literacy on planning accuracy. A Bayesian linear regression model was fit with log-transformed absolute error as the outcome variable and energy literacy score as the predictor, controlling for random effects of participant and state. This

Figure 6

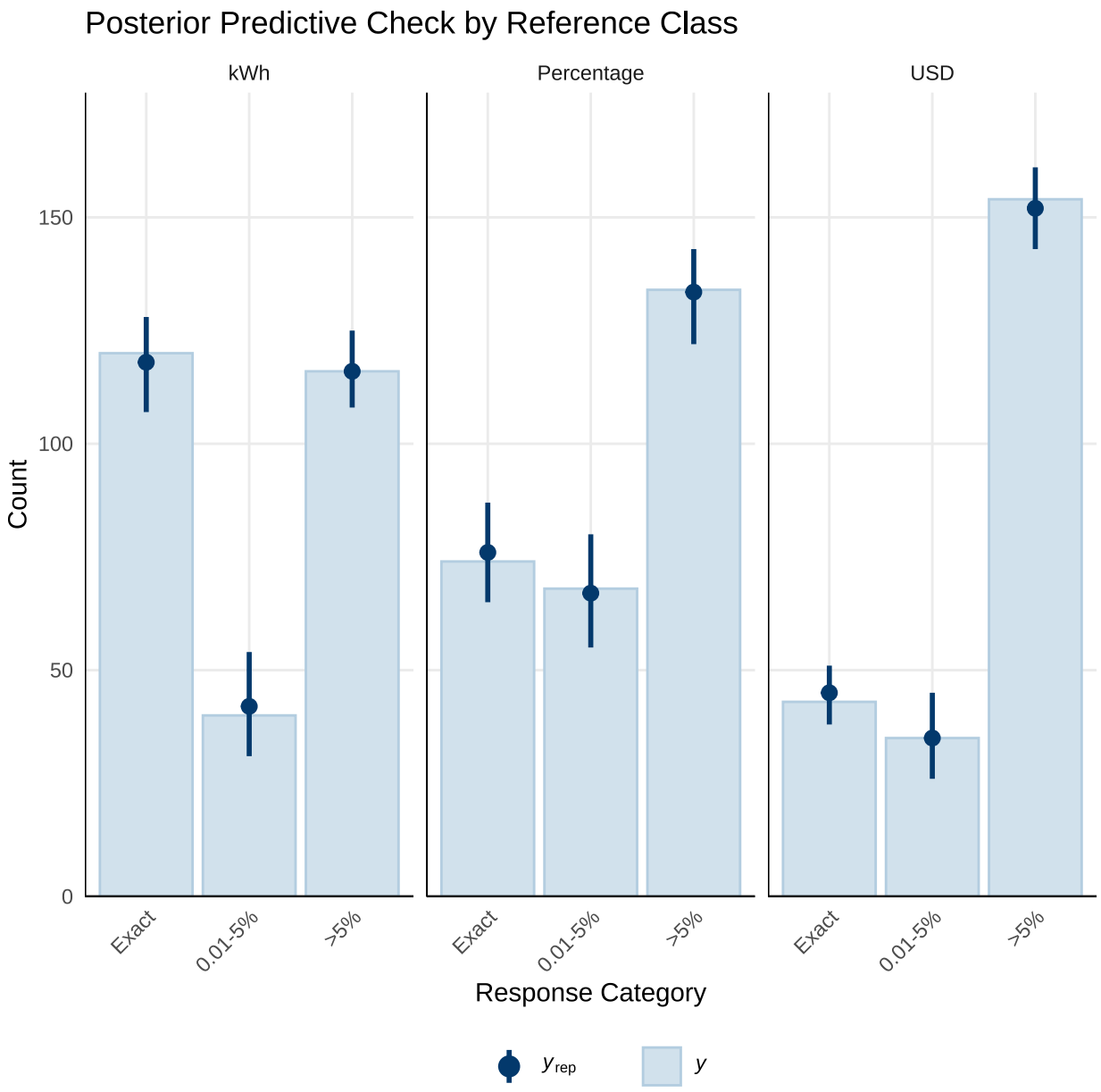
Experiment 2. Average marginal effects of reference class on accuracy levels



Note. The points represent the average change in the probability of each accuracy level when switching from the kWh reference class to Percentage (red) or USD (green). Error bars indicate 95% credible intervals. The results show that, compared to kWh, the Percentage format decreases the probability of an "Exact match" by 7.0% and increases the probability of "Over 5% error" by 6.9%. The USD format has a larger negative effect on "Exact match" (-14.7%) and a larger positive effect on "Over 5% error" (+16.5%). The effects on the "0.01-5% error" category are near zero for both comparisons.

Figure 7

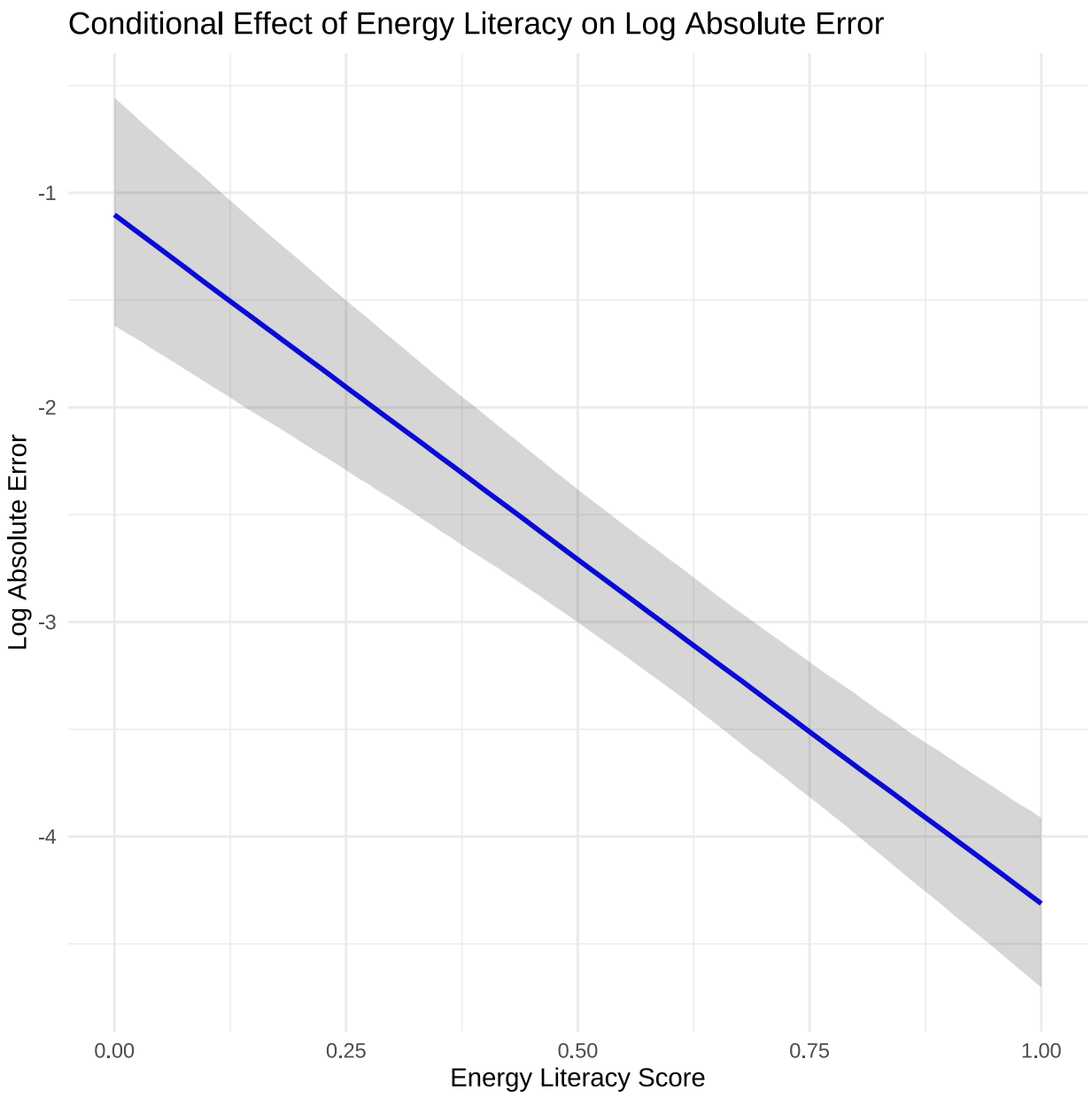
Experiment 2. Posterior predictive check of the bayesian regression model



Note. Posterior predictive check for the Bayesian ordinal regression model. Blue bars show the observed frequencies for each accuracy level (Exact match, 0.01-5% error, and Over 5% error), dots with error bars represent the model predictions. The plot is faceted by reference class condition (kWh, Percentage, USD).

Figure 8

Experiment 2. Conditional effect of energy literacy on log absolute error



Note. The plot shows the relationship between energy literacy score and log absolute error, controlling for random effects of participant and state. Higher energy literacy scores are associated with smaller deviations from the target reduction goal, indicating more accurate planning.

revealed a significant negative relationship between energy literacy and log absolute error (Estimate = -3.21, 95% CI: [-3.89 to -2.52]), indicating that participants with higher energy literacy scores tended to have smaller deviations from the target reduction goal, and thus more accurate plans overall (Figure 8).

Experiment 2: Discussion

Experiment 2 aimed to build upon the findings of Experiment 1 by replicating the core manipulation of reference class. Additionally, it incorporated variables that might influence planning accuracy. These included goal difficulty and the way that the prior year's usage was presented (rounded or exact). The results largely converged with those of Experiment 1, providing further converging evidence that presenting energy reduction goals in absolute units (kWh) facilitates more accurate planning compared to percentage-based or monetary formats.

Taken together, the results of Experiment 2 provide further support for the hypothesis that presenting energy reduction goals in absolute units (kWh) leads to more accurate planning compared to percentage-based or monetary formats.

The finding that the more challenging 15% reduction goal was associated with a slight improvement in accuracy is counterintuitive. It may be that participants put more effort into the task under this condition, or perhaps this is an artifact of the way that the task was presented. However, this effect was relatively small and thus should be explored in future research to confidently establish its existence. Furthermore, the magnitude of the effect size of this manipulation should be examined to better understand the practical implications of goal difficulty for energy conservation.

The large and significant effect of calculator use, consistent across both experiments, underscores the crucial role of tools that individuals are likely to employ in real-world settings. Finally, the consistent relationship between energy literacy and accuracy, observed across both experiments, highlights the potential value of educational interventions aimed at improving consumers' understanding of energy concepts.

General Discussion

The principal aim of this research was to investigate how the numerical format used to convey energy reduction goals influences consumers' capacity to formulate accurate, appliance-level energy conservation plans. Across two experiments employing a simulated household planning task, the findings consistently demonstrated a significant advantage for presenting goals in absolute, physical units. Specifically, framing reduction targets in kilowatt-hours (kWh) resulted in markedly greater planning accuracy compared to conditions where equivalent goals were presented as percentages or in monetary terms (USD). This primary finding proved robust across variations in hypothetical family household scenarios and secondary task manipulations, including goal difficulty (Exp 2: 10% vs. 15% reduction) and the precision of provided baseline data (Exp 2: exact vs. rounded values).

The observed superiority of the kWh format may be understood through several complementary frameworks, primarily centered on cognitive load and representational compatibility. The kWh format may minimize cognitive load, primarily through maximizing unit consistency inherent within the planning task itself (Sweller, 1988). Participants were required to manipulate appliance usage figures invariably presented in kWh, performing subtractions from baseline usage, allocating targeted reductions, and summing resultant changes. When the reduction goal was expressed in kWh, this direct correspondence between the target unit and the operational data obviated the necessity for intermediate unit conversions. Furthermore, given that kWh function as a direct, linear metric of energy consumption, their use potentially circumvents cognitive biases documented with non-linear efficiency metrics (Larrick & Soll, 2008) and might serve more effectively as a 'default unit' (Herberz et al., 2020) for this particular planning context, thereby grounding the goal in a more readily manipulable quantity. Kilowatt-hours, while perhaps less universally familiar than monetary units in everyday discourse for some consumers, nonetheless represent the fundamental unit of electricity consumption frequently encountered on utility bills and appliance labeling.

Conversely, the comparatively diminished performance for Percentage and USD format

conditions highlights the cognitive costs potentially incurred due to format incongruence within this specific task. Both alternative formats introduced what might be termed an asymmetric conversion burden: participants first needed to translate the relative (percentage) or derived (monetary) goal into an absolute kWh value prior to engaging with the central task of allocating reductions across kWh-denominated appliance figures. This initial translation step intrinsically elevates cognitive load and introduces a critical juncture prone to calculation errors, particularly considering the documented difficulties many individuals exhibit concerning proportional reasoning (Fisher & Mormann, 2022; Peters et al., 2006).

The consistently lowest accuracy observed with the USD format is particularly noteworthy. While monetary feedback is sometimes preferred (Karjalainen, 2011; Nemati & Penn, 2020) or aids certain decisions like cost-based appliance selection (Blasch et al., 2019), our results highlight optimal formatting's task-dependence. For detailed allocation, the required translation from USD to kWh appears to introduce critical computational friction, potentially compounded by reliance on ill-suited cost heuristics (Van Den Broek & Walker, 2019).

Secondary findings, primarily emerging from Experiment 2, offer additional, albeit preliminary, insights. The substantial improvement in planning accuracy associated with self-reported calculator use serves to highlight the computational demands inherent in the planning task and illustrates the practical benefits derived from leveraging cognitive offloading tools (Risko & Gilbert, 2016). Importantly, the main effect of information format persists when statistically controlling for calculator. Experiment 2 also tentatively suggested a modest accuracy improvement when baseline usage data were presented using rounded numbers, a finding potentially attributable to reduced processing fluency demands (Nguyen et al., 2022), although this particular effect warrants more dedicated future investigation. Finally, the unexpected, preliminary indication that the ostensibly more challenging 15% reduction goal was associated with slightly enhanced accuracy remains statistically uncertain and necessitates replication before any substantive interpretation can be confidently advanced. Furthermore, in line with (Attari et al., 2010; Canfield et al., 2017), individuals possessing higher energy literacy consistently

demonstrated more accurate planning across all format conditions.

Although consumers may, under certain circumstances, prefer or derive benefit from monetary energy information (e.g., for global cost assessments, long-term investment decisions), the specific task of precisely planning near-term, appliance-level consumption adjustments seems significantly facilitated when information is presented using the direct, absolute units of energy itself (kWh). This observation aligns with broader research indicating that individuals tend to gravitate towards concrete cues in energy-related judgments (Van Den Broek & Walker, 2019) and that interventions furnishing specific heuristics or employing well-chosen "default units" can enhance accuracy and guide more optimal decisions (Herberz et al., 2020; Marghetis et al., 2019). The current findings suggest, that the selection of information format can itself function as a subtle yet potentially effective "nudge," guiding individuals towards more accurate energy planning by reducing the cognitive burden associated with translating abstract goals into concrete, actionable steps. This work extends prior investigations into the effects of numerical format within comprehension and decision-making contexts (Gigerenzer & Edwards, 2003; Reimer et al., 2015) by demonstrating the persistence of such format-dependent effects within a more complex, goal-directed planning paradigm necessitating multi-step calculation and resource allocation, as opposed to simpler estimation or choice tasks.

Limitations and Future Directions

Several limitations in the current studies should be considered when interpreting these findings. Real-world conservation decisions occur amid comfort trade-offs, fluctuating prices, and social norms - all of which are factors absent from our controlled tasks. Consequently, planning accuracy in this paradigm may not perfectly predict the efficacy of planning or subsequent behavior change in naturalistic environments. Additionally, our primary outcome measure of planning accuracy does not capture other potentially important dimensions such as the perceived feasibility or acceptability of the generated plan. Finally, the Percentage and USD conditions required an additional calculation step compared to the kWh condition - though we argue that these additional computations reflect a practical reality of using these formats for this task.

Additionally, although we recorded whether participants used calculators, we could not control how thoroughly they engaged in mathematical computations, nor could we track other external resources they might have consulted.

These limitations, alongside the core findings, suggest several avenues for future research. Among these is the need for field experiments to ascertain whether the planning accuracy benefits conferred by the kWh format translate into demonstrable, sustained energy savings in real households facing actual constraints and consequences. Investigating the interplay between information format and individual differences beyond general energy literacy (e.g., factors such as numeracy, financial literacy, cognitive style, and motivational orientations) could reveal moderating factors and facilitate the development of more precisely tailored communication strategies. Employing process-tracing methodologies, such as think-aloud protocols, would afford valuable insights into the specific cognitive strategies, heuristics, and experienced cognitive load elicited by different formats, thereby further elucidating the mechanisms underpinning the observed accuracy discrepancies.

Conclusion

In conclusion, this research provides clear evidence that the numerical format chosen to communicate energy-saving goals exerts a significant influence on the accuracy with which consumers can develop conservation plans. Framing reduction targets in absolute, linear consumption units (kWh) - the standard unit for quantifying electricity usage enhances planning accuracy compared to relative percentages or derived monetary values (USD). Although future work is needed to validate these results in authentic, real-world contexts and across broader demographic samples, the present findings provide strong evidence that absolute consumption metrics (e.g., kWh) can substantially enhance the precision and potentially the effectiveness of residential energy planning.

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