

1           **Quadratic Survey Interface**

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3           **ANONYMOUS AUTHOR(S)\***

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5           Quadratic Surveys (QS) elicit more accurate individual preferences than traditional surveys, such as Likert-scale surveys. However, the  
6           cognitive load associated with QS has hindered its adoption in digital surveys for collective decision-making. We introduce a two-phase  
7           “organize-then-vote” QS interface based on decision-making and preference construction theories designed to lessen the cognitive load.  
8           Since interface design significantly impacts survey results and accuracy, our design scaffolds survey takers’ decision-making while  
9           managing the cognitive load imposed by QS. In a 2x2 between-subject in-lab study on public resource allotment, we compared our  
10          interface with a traditional text interface across QS with 6 (short) and 24 (long) options. Our interface reduced satisficing behaviors  
11          arising from cognitive overload in long QS conditions. Participants using our interface in the long QSs shifted their cognitive effort  
12          from mechanical operations to constructing more comprehensive preferences. This research clarifies how human-centered design  
13          improves preference elicitation tools for collective decision-making.

14  
15          CCS Concepts: • **Human-centered computing → Collaborative and social computing systems and tools; Collaborative and**  
16          **social computing design and evaluation methods; User studies; HCI design and evaluation methods; Interactive systems**  
17          **and tools; Empirical studies in interaction design.**

18  
19          Additional Key Words and Phrases: Quadratic Voting; Survey Response Format; Collective decision-making; Preference Construction

20  
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23  
24          **1 Introduction**

25  
26          Designing effective survey interfaces is crucial for accurately capturing respondents’ preferences, which directly impact  
27          the quality and reliability of the data collected. For instance, voice assistants have been used to gather user feedback [1],  
28          and a recent Human-Computer Interaction (HCI) study highlights that certain survey response formats can increase  
29          errors [2]. In this paper, we introduce **Quadratic Surveys (QS)**, a survey tool designed to elicit preferences more  
30          accurately than traditional methods [3]. Despite the promise of QS, there has been no research on designing interfaces  
31          to support its unique quadratic mechanisms [4], where participants must rank and rate items — a task that poses  
32          significant cognitive challenges. To popularize QS and ensure high-quality data, this paper addresses the question: *How*  
33          *can we design interfaces to support participants in completing Quadratic Surveys (QS) more effectively?*

34  
35          We envision an effective interface that navigates participants through the complex mechanism and preference  
36          construction process, tailored to the unique challenges of QS. QS improves accuracy in individual preference elicitation  
37          compared to traditional methods like Likert scales by requiring participants to make trade-offs using a fixed budget  
38          of credits, where purchasing  $k$  votes for an option in QS costs  $k^2$  credits [5, 3]. This quadratic cost structure forces  
39          respondents to carefully evaluate their preferences, balancing the strength of their support or opposition against the  
40          limited budget. While this cost structure forces them to make thoughtful trade-offs, this complexity also increases

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53 cognitive load, making it mentally taxing to weigh costs, evaluate options, and construct rankings [6]. Moreover, QS,  
54 often referred to as Quadratic Voting (QV) in voting scenarios, can involve hundreds of options [7, 8], increasing the  
55 risk of cognitive overload and satisficing [9, 10, 11]. We propose that an effective interface tailored to support users  
56 through these complex trade-offs can reduce cognitive load and facilitate better preference construction.  
57

58 To date, existing quadratic mechanism-powered applications simply present options, allow vote adjustments and  
59 automatically calculate votes, costs, and budget usage. These designs focused heavily on the mechanism, rather than  
60 supporting possible challenges these application users faced. Survey interface literature, while addressing decision-  
61 making and usability, most focus on traditional surveys that do not share the unique option-to-option trade-offs that QS  
62 introduces [12, 13, 14, 15, 16, 2]. The challenges, in particular, cognitive load [17, 18, 15, 19] and scaffolding challenging  
63 tasks [20, 21, 22] like preference construction, are opportunities where user interfaces have shown their promises. As  
64 a result, it remains unclear how different interface designs might support QS in reducing cognitive load and aiding  
65 preference construction.  
66

67 After multiple design iterations, we propose a novel interactive two-phase “organize-then-vote” QS interface (two-  
68 phase interface, Figure 3) that integrates three key elements. First, the interface scaffolds the preference construction  
69 process by having participants initially categorize the survey options into “Positive,” “Neutral,” or “Negative.” This  
70 serves as a cognitive warm-up, easing participants into the more complex QS voting task. Second, the interface arranges  
71 the options according to these categorizations, providing a structured visual layout. Third, participants can refine the  
72 positions of these options using drag-and-drop functionality, giving them greater control and agency in the preference-  
73 construction process. These design features are aligned with preference construction theory and build upon prior  
74 research in interface design to reduce cognitive load and enhance user engagement.  
75

76 To explore how these interface elements mitigate the cognitive load and support preference construction in Quadratic  
77 Surveys, we pose the following research questions:  
78

- 79 • RQ1. How does the number of options in Quadratic Surveys impact respondents’ cognitive load?
- 80 • RQ2a. How does the two-phase interface impact respondents’ cognitive load compared to a text interface?
- 81 • RQ2b. What are the similarities and differences in sources of cognitive load across the two interfaces?
- 82 • RQ3. What are the differences in Quadratic Survey respondents’ behaviors when coping with long lists of  
83 options across the two-phase interface and the text interface?

84 We invited 41 participants to a lab study comparing our two-phase interface with a baseline to understand how  
85 different interface designs and option lengths impact cognitive load. Qualitative findings, measured using the NASA  
86 Task Load Index (NASA-TLX) and semi-structured interviews, revealed that participants using the two-phase interface  
87 experienced cognitive demand more from strategic, holistic thinking compared to personal relevance and operational  
88 tasks, particularly in longer surveys. Quantitative results showed that, although participants spent more time per option,  
89 they made faster decisions during the voting phase, suggesting a more efficient distribution of cognitive effort. We  
90 concluded that the two-phase interface prevented cognitive overload in long QS surveys and shifted mental load toward  
91 more strategic thinking, reducing reliance on mental shortcuts like satisficing [9].  
92

93 *Contributions.* We contribute to the HCI community by proposing the first interface specifically designed for QS  
94 and QV-like applications, aimed at reducing cognitive challenges and scaffolding preference construction through a  
95 two-phase interface with direct manipulation. Before our work, no research had explored QS interfaces, particularly for  
96 long surveys prone to cognitive overload. Few studies in HCI address interfaces for surveys and questionnaires. Our  
97 study demonstrated how user interfaces can facilitate preference construction in situ and reduce satisficing behaviors  
98

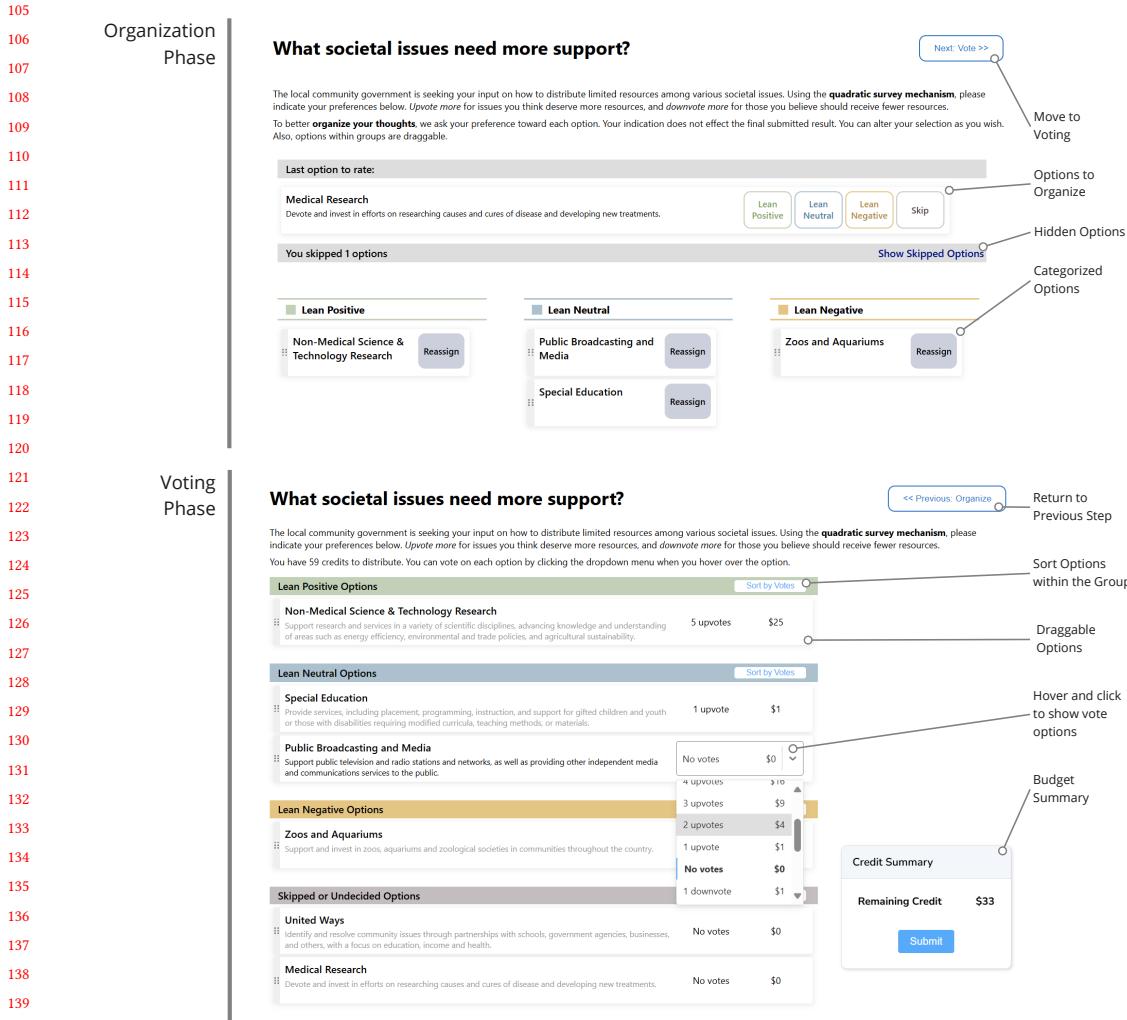


Fig. 1. The Two-Phase Interface: The interface consists of two phases. Survey respondents can navigate between phases using the top right button. In the organization phase, the interface presented one option at a time to the respondents where they choose among four choices: “Lean Positive”, “Lean Neutral”, “Lean Negative”, or “Skip”. Skipped options are hidden and can be evaluated later. The chosen options will be listed below. Items can be dragged and dropped across categories or returned to the stack. In the voting phase, options are listed in the order of the four categories. When hovering over each option, respondents can select a vote for that option using the dropdown. Each dropdown contains the cost associated with the vote. A sort button allows ascending sorting within each category. A summary box tracks the remaining credit balance.

by promoting incremental updates and deeper engagement with survey items through interface elements. Additionally, our interview is also the first in-depth qualitative analysis of user experiences with Quadratic Mechanism applications, identifying key factors contributing to cognitive load. The impact of our contribution extends beyond QS, offering design implications for other preference-elicitation tools in complex scenarios. By making QS easier to use and more accurate, our design also encourages wider adoption among researchers and practitioners. Finally, our work lays the

157 groundwork for future studies on qualitative insights and future interface designs of quadratic mechanisms, supporting  
 158 decision-makers in eliciting accurate respondents' preferences.  
 159

## 160 2 Related Work

162 This research lies at the intersection of three core areas: quadratic surveys, survey and voting interface design, and  
 163 choice overload along with cognitive challenges. In this section, we review the related works in each of these areas.  
 164

### 166 2.1 Quadratic Survey and the Quadratic Mechanism

167 We introduce the term **Quadratic Survey (QS)** to describe surveys that utilize the quadratic mechanism to collect  
 168 individual attitudes. The **quadratic mechanism** is a theoretical framework designed to encourage the truthful revelation  
 169 of individual preferences through a quadratic cost function [4]. This framework gained popularity through **Quadratic**  
 170 **Voting (QV)**, also known as plural voting, which uses a quadratic cost function in a voting framework to facilitate  
 171 collective decision-making [23].  
 172

173 To illustrate how QS works, we formally define the mechanism: each survey respondent is allocated a fixed budget,  
 174 denoted by  $B$ , to distribute among various options. Participants can cast  $n$  votes for or against option  $k$ . The cost  $c_k$  for  
 175 each option  $k$  is derived as:  
 176

$$178 \quad c_k = n_k^2 \quad \text{where} \quad n_k \in \mathbb{Z}$$

180 The total cost of all votes must not exceed the participant's budget:  
 181

$$182 \quad \sum_k c_k \leq B$$

185 Survey results are determined by summing the total votes for each option:  
 186

$$187 \quad \text{Total Votes for Option } k = \sum_{i=1}^S n_{i,k}$$

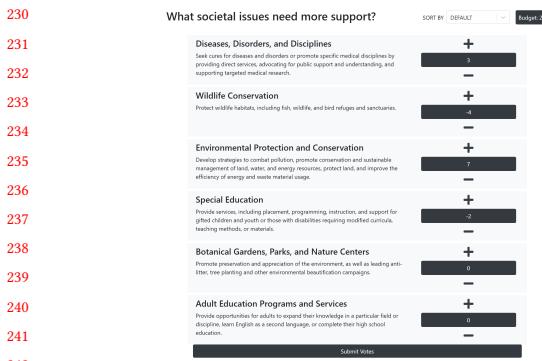
189 where  $S$  represents the total number of participants, and  $n_{i,k}$  is the number of votes cast by participant  $i$  for option  $k$ .  
 190 Each additional vote for each option increases the marginal cost linearly, encouraging participants to vote proportionally  
 191 to their level of concern for an issue [24].  
 192

193 QS adapts these strengths of the quadratic mechanism in *voting* to encourage truthful expression of preferences in  
 194 *surveys*. Unlike traditional surveys that elicit either rankings *or* ratings, QS allows for *both*, enabling participants to cast  
 195 multiple votes for or against options, incurring a quadratic cost. Cheng et al. [3] showed that this mechanism aligns  
 196 individual preferences with behaviors more accurately than Likert Scale surveys, particularly in resource-constrained  
 197 scenarios like prioritizing user feedback on user experiences.  
 198

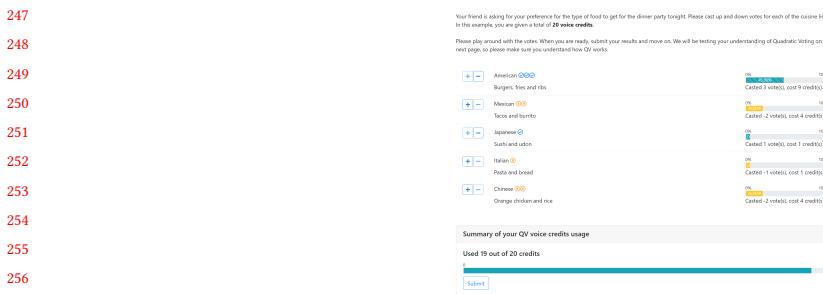
199 In recent years, empirical studies on QV have expanded into various domains [25, 26]. Applications based on the  
 200 quadratic mechanism have also grown, including Quadratic Funding, which redistributes funds based on outcomes  
 201 from consensus made using the quadratic mechanism [27, 28]. Recent work by South et al. [29] applies the quadratic  
 202 mechanism to networked authority management, later used in Gov4git [30]. Despite the increasing breadth and depth  
 203 of applications utilizing the quadratic mechanism, little attention has been paid to user experience and interface design,  
 204 which support individuals in expressing their preference intensity. Our work aims to address this by designing interfaces  
 205 supporting quadratic mechanisms.  
 206



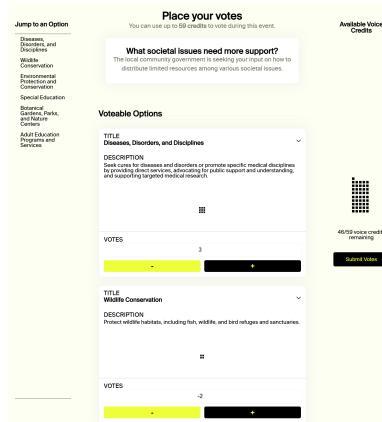
(a) Software by WeDesign, used in the first empirical QV research [5]. Little information is available about the software, except for an image from Posner and Weyl [24]. In the image, each prompt has thumbs up and down icons to update the vote in the center. The remaining budget appears as a progress bar at the top.



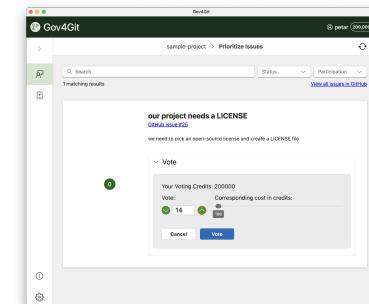
(c) An open-source QV interface [34] offers a publicly available service. Options show only the current number of votes, with credits displayed in the top right corner. This interface does not show the costs of votes but supports sorting options.



(e) The interface used in the research by Cheng et al. [3] employs the most visual components. Icons depict the current number of votes, with progress bars signifying the current spending.



(b) An open-sourced QV interface [31] forked from GitCoin [32], used by the RadicalxChange community [33]. This interface presents total credits as small blocks. Votes are updated using plus and minus buttons, with numerical counts shown under each option and surface area as costs.



(d) The interface designed for gov4git [30] updates votes using arrows under each option, with the associated cost shown as a percentage bar to the right. A search bar exists for searching specific pull requests or issues.

Fig. 2. Recent interface for applications using the quadratic mechanism. Manuscript submitted to ACM

## 2.2 Design Implications from Surveys and Voting Interfaces

We began by examining existing QV applications, which share the same mechanism as QS, and identifying shared interface components. All QV interfaces generally include:

- Option list: A list of options for voting.
  - Vote controls: Buttons to increase or decrease votes for each option.
  - Individual vote tally: A display of the votes cast per option.
  - Summary: An auto-generated summary of costs and the remaining budget.

These components present options, calculate costs, and allow vote adjustments. However, these interfaces focus purely on mechanics without little understanding of voter's usability needs or offering cognitive support to help them complete the task effectively. In addition, the HCI community conducted few research [35, 36] on survey and questionnaire interfaces components, with more work focusing more on alternative input modalities like bots, voice, and virtual reality [37, 38, 39, 40]. Thus, we turn to marketing and research literature for insights into how digital survey interface elements can impact user behavior and usability.

Research in the marketing and research communities focusing on survey and questionnaire design, usability, and interactions examines the influence of presentation styles and ‘response format.’ Weijters et al. [41] demonstrated that horizontal distances between options are more influential than vertical distances, with the latter recommended for reduced bias. Slider bars, which operate on a drag-and-drop principle, show lower mean scores and higher nonresponse rates compared to buttons, indicating they are more prone to bias and difficult to use. In contrast, visual analog scales that operate on a point-and-click principle perform better [42]. These studies show how even small design changes can have a large impact on usability, highlighting the importance of designing interfaces that prioritize human-centered interaction rather than focusing solely on functionality.

Voting interfaces are a specialized type of survey interface that not only elicit individual choices but often have consequential impacts. For example, the butterfly ballot, an atypical design, may have influenced the outcome of the 2000 U.S. Presidential Election [43]. Research has shown that ballot interfaces can significantly influence democratic processes [12, 44, 45]. Several studies also highlighted how voting interface designs shift voter decisions [12], reduce usability errors [46, 47], or improve interaction [48, 49, 50, 51, 52]. We provide more details to these voting interfaces in the Appendix A.

From the QV implementations, response format literature, and voting interfaces, we identified how interfaces significantly influence respondent behavior, decision accuracy, and cognitive load. While these systems are functional, they lack the human-centered design needed to reduce cognitive load and make them truly usable, rather than simply operable. These burdens are especially problematic for complex systems like QS, where high cognitive demands may deter researchers and users alike. Developing effective, human-centered interfaces for QS could enhance usability, reduce cognitive overload, and increase adoption in both research and practical applications.

### 2.3 Cognitive Challenges and Choice Overload

The challenge of respondents making difficult decisions using quadratic mechanisms remains unexplored in the literature. Lichtenstein and Slovic [6] identified three key elements that make decisions difficult. These elements include making decisions in unfamiliar contexts, being forced to make tradeoffs due to conflicting choices, and quantifying the value of one's opinions. OS fits all three elements: participants may encounter unfamiliar options set by the decision

313 maker, are constrained by budgets that require tradeoffs, and cast final votes as numerical values. Thus, we believe QS  
314 introduces high cognitive load.  
315

316 Cognitive overload can adversely affect performance, leading individuals to rely on heuristics rather than deliberate,  
317 logical decision-making [53]. When presented with excessive information, such as too many options, individuals  
318 'satisfice', settling for a 'good enough' solution rather than an optimal one [9, 10, 11]. Subsequently, too many options  
319 can overwhelm individuals, resulting in decision paralysis, demotivation, and dissatisfaction [54].  
320

321 Additionally, Alwin and Krosnick [55] highlighted that the use of ranking techniques in surveys can be time-  
322 consuming and potentially more costly to administer. These challenges are compounded when ranking numerous items,  
323 requiring substantial cognitive sophistication and concentration from survey respondents [56].  
324

325 Notable applications of Quadratic Voting include the 2019 Colorado House, which considered 107 bills [57], and  
326 the 2019 Taiwan Presidential Hackathon, which featured 136 proposals [58]; both used a single QV question with  
327 hundreds of options. Psychological and behavioral research highlights the importance of understanding how individuals  
328 navigate and benefit from new interfaces under long-list QS conditions. These empirical applications of QV suggest  
329 QS's potential to elicit individual preferences, emphasizing the need to study cognitive load and interface design.  
330

### 331 3 Quadratic Survey Interface Design

332 In this section, we present the QS interface. Using components identified in current QV interfaces, together with prior  
333 literature, we iterated over paper prototypes and three design iterations based on each pre-test result. For coherence  
334 and brevity, we provide detailed descriptions of these iterations and additional design considerations in Appendix B.  
335

#### 336 3.1 Quadratic Voting interfaces in the wild

337 During our initial paper prototyping iterations, two challenges emerged: identifying relative preferences among options  
338 and deciding the degree of trade-offs between options. In this study, we focus on the first challenge to inform our  
339 interface design iterations.  
340

#### 341 3.2 The Two-Phase Interface

342 3.2.1 *Justifying a two-phase approach.* The main objective for the two-phase interface is to facilitate preference  
343 construction and reduce cognitive load. The two-phase interface, shown in Figure 3 consists of two steps: An organization  
344 phase and a voting phase. Throughout both phases, survey respondents can drag-and-drop options across the presented  
345 option list.  
346

347 A *two-phase approach*. If preferences are constructed, by nature, they consist of a series of constructed decision-making  
348 processes [6]. Two major decision-making theories informed this two-step interaction interface design: Montgomery  
349 [59]'s Search for a Dominance Structure Theory (Dominance Theory) and Svenson [60]'s Differentiation and Consoli-  
350 dation Theory (Diff-Con Theory). The former suggested that decision-makers prioritize creating dominant choices  
351 to minimize cognitive effort by focusing on evidently superior options [59]. The latter described a two-phase process  
352 where decisions are formed by initially *differentiating* among alternatives and then *consolidating* these distinctions to  
353 form a stable preference [60]. Both theories supported the design decision to reduce the dimensions during the initial  
354 decision process and help emphasize relatively important options to form decisions. Hence, the two-phase design –  
355 organize then vote – aimed to facilitate this cognitive journey explicitly. The first phase focused on differentiating and  
356 identifying dominant options, enabling survey respondents to preliminarily categorize and prioritize their choices. The  
357

365 second phase presented these categorized options in a comparable manner, with drag-and-drop functionality, enhancing  
 366 one's ability to consolidate preferences. This structured approach aimed to construct a clear decision-making procedure  
 367 that reduced cognitive load and enhanced clarity and confidence in the decisions made.  
 368

369

370

371 Organization  
372 Phase

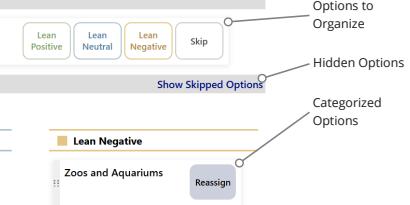
### What societal issues need more support?

The local community government is seeking your input on how to distribute limited resources among various societal issues. Using the **quadratic survey mechanism**, please indicate your preferences below. *Upvote* more for issues you think deserve more resources, and *downvote* more for those you believe should receive fewer resources.  
 To better **organize your thoughts**, we ask your preference toward each option. Your indication does not effect the final submitted result. You can alter your selection as you wish. Also, options within groups are draggable.

Last option to rate:

#### Medical Research

Devote and invest in efforts on researching causes and cures of disease and developing new treatments.



You skipped 1 options

#### Lean Positive

##### Non-Medical Science & Technology Research

Reassign

#### Lean Neutral

##### Public Broadcasting and Media

Reassign

##### Special Education

Reassign

#### Lean Negative

##### Zoos and Aquariums

Reassign

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Voting  
Phase

### What societal issues need more support?

The local community government is seeking your input on how to distribute limited resources among various societal issues. Using the **quadratic survey mechanism**, please indicate your preferences below. *Upvote* more for issues you think deserve more resources, and *downvote* more for those you believe should receive fewer resources.  
 You have 59 credits to distribute. You can vote on each option by clicking the dropdown menu when you hover over the option.

<< Previous Organize

Return to  
Previous Step

Sort Options  
within the Group

Draggable  
Options

Hover and click  
to show vote  
options

Budget  
Summary

#### Lean Positive Options

##### Non-Medical Science & Technology Research

Support research and services in a variety of scientific disciplines, advancing knowledge and understanding of areas such as energy efficiency, environmental and trade policies, and agricultural sustainability.

5 upvotes \$25

1 upvote \$1

No votes \$0

4 upvotes \$10

3 upvotes \$9

2 upvotes \$4

1 upvote \$1

No votes \$0

1 downvote \$1

No votes \$0

Sort by Votes

417     *Phase 1: Organization Phase.* The goal of the organization phase was to support participants in identifying dominating  
418     options or partitioning options into differentiable groups. In this section, we first describe how the interaction worked,  
419     then we detail the reasons for the implemented design decisions.  
420

421     The organizing interface, depicted on the top half of Figure 3, sequentially presented each survey option. Participants  
422     selected a response among three ordinal categories – “lean positive”, “lean negative”, or “lean neutral”. Once selected, the  
423     system moved that option to the respective category. Participants could skip the option if they did not want to indicate  
424     a preference. Options within the groups were draggable and rearrangeable to other groups should the participants wish.  
425

426     Strack and Martin [61]’s research showed that upon understanding a survey question, respondents either recalled a  
427     prior judgment or constructed a new one when completing an attitude survey. In addition, revealing one option at a  
428     time gated the amount of information presented to the survey respondent and thereby reduced the extraneous load [62].  
429     This process allowed participants to form or express opinions on individual options incrementally. This design also  
430     mitigated the original concern from early prototypes where participants accidentally treated the organizing task as a  
431     ranking task.  
432

433     The three possible options, positive, neutral, and negative, aimed to scaffold participants in constructing their own  
434     choice architecture [63, 64], which strategically segmented options into diverse and alternative choice presentations  
435     while avoiding the biases from defaults. We believed that these three categories were sufficient for participants to  
436     segment the options. However, we chose not to limit the number of options one could place into a category to prevent  
437     restricting user agency, a core user interface design principle [18].  
438

439     Immediate feedback displaying the placement of options and allowing participants to rearrange them via drag-and-  
440     drop adhered to key interface design principles [18]. At the same time, it allowed finer grain control for individuals to  
441     surface dominating options and create differentiating groups of options.  
442

443  
444     *Phase 2: Interactive Voting Phase.* The objective of the voting phase was to facilitate the consolidation of differentiated  
445     options through interactive elements while reinforcing the differentiation across options constructed by participants from  
446     the previous phase. This facilitation was achieved by retaining the drag-and-drop functionality for direct manipulation  
447     of position and enabling sorting within each category.  
448

449     Options were displayed as they were categorized within each category from the previous step and in the following  
450     section orders – lean positive, lean neutral, lean negative, and skipped or undecided as detailed on the bottom half  
451     of Figure 3. The Skipped or Undecided category contained options left in the organization queue, possibly because  
452     survey respondents had a pre-existing preference or chose not to organize their thoughts further. The original order  
453     within these categories was preserved to maintain and reinforce the differentiated options. This new ordering sequence  
454     mitigated the concern from prototype 3 where options without a category are left at the top of the voting interface.  
455     Respondents had the flexibility to return to the organization interface at any point during the survey to revise their  
456     choices.  
457

458     In the voting interface, options remained draggable, enabling participants to modify or reinforce their preference  
459     decisions as needed. Each category featured a sort-by-vote function that enabled reordering within the same category.  
460     Although these interactions did not influence the final voting outcome, they were designed to support consolidation  
461     and positional proximity in information organization. This design aimed to automate the grouping of similar options  
462     while providing an intuitive drag-and-drop mechanism, thereby facilitating decision-making by placing similar options  
463     near each other. This echoed the principles of the proximity compatibility principle, particularly emphasizing spatial  
464     proximity.  
465

<sup>469</sup> proximity and mental compatibility [65]. The interface design anticipated that participants would find it easier to  
<sup>470</sup> consolidate their choices when similar options were positioned close together, thereby reducing cognitive load.  
<sup>471</sup>

<sup>472</sup> While multiple interaction mechanisms exist, drag-and-drop has been extensively explored in rank-based surveys.  
<sup>473</sup> For instance, Krosnick et al. [66] demonstrated that replacing drag-and-drop with traditional number-filling rank-based  
<sup>474</sup> questions improved participants' satisfaction with little trade-off in their time. Similarly, Timbrook [67] found that  
<sup>475</sup> integrating drag-and-drop into the ranking process, despite potentially reducing outcome stability, was justified by the  
<sup>476</sup> increased satisfaction and ease of use reported by respondents. The trade-off was deemed worthwhile as QS did not use  
<sup>477</sup> the final position of options as part of the outcome if it significantly enhanced user satisfaction and usability [68].  
<sup>478</sup>

<sup>479</sup> Together, these design decisions led to our belief that a two-phase interface with direct interface manipulation could  
<sup>480</sup> reduce the cognitive load for survey respondents to form preference decisions when completing QS.  
<sup>481</sup>

<sup>482</sup>

<sup>483</sup> 3.2.2 *Aesthetic Design Decisions.* We made three aesthetic design decisions. First, we decided to remove all visual  
<sup>484</sup> elements. Prior literature suggested that the use of emojis might influence the interpretations of surveys [69] and  
<sup>485</sup> decrease user satisfaction [15]. Prior literature also noted that not all data visualization elements reduce cognitive  
<sup>486</sup> demand [70]. Even though effective visualization can aid decision-making, it remains an open question that this study  
<sup>487</sup> does not aim to address. Thus, we also removed all visualization elements, such as blocks, progress bars, and percentage  
<sup>488</sup> indicators.  
<sup>489</sup>

<sup>490</sup> Second, the final interface has all options presented on the screen at the same time, intentionally. Unlike all the  
<sup>491</sup> prototypes and existing interfaces, prior literature emphasized the importance of placing all the options on the same  
<sup>492</sup> digital ballot screen to avoid losing votes. This echoes the proverb "out of sight, out of mind," where individuals might  
<sup>493</sup> be biased toward options that are shown to them, and additional effort is required for individuals to retrieve specific  
<sup>494</sup> information if options are hidden.  
<sup>495</sup>

<sup>496</sup> Last, we decided to use a dropdown positioned to the right of the option such that control of votes and the budget  
<sup>497</sup> summary are placed near one another. The layout of the votes and cost was inspired by online shopping cart checkout  
<sup>498</sup> interfaces where quantities are supplied next to the itemized costs followed by the total checkout amount. We chose  
<sup>499</sup> a dropdown after iterating with two alternative input methods (Figure 4): the original click-based buttons and a  
<sup>500</sup> wheel-based implementation. The former design requires survey respondents to click multiple times to reach their  
<sup>501</sup> desired vote values. Thus, we wanted to look for a solution to aid respondents in reaching their intended value faster. A  
<sup>502</sup> wheel-based approach allows intuitive control of the votes by using the wheel on the mouse and clicking to fine-tune  
<sup>503</sup> the values. However, in our early pilot studies, not all participants were familiar with wheel control. Thus, we opted for  
<sup>504</sup> a dropdown menu for vote selection.  
<sup>505</sup>

### <sup>506</sup> 3.3 Text-based Interface <sup>507</sup>

<sup>508</sup> To compare how the designed interactive components influenced participants' cognitive load and behavior, we designed  
<sup>509</sup> the text-based interface as our control condition. The text-based interface shares the other functionalities of the two-  
<sup>510</sup> phase interface without the two-phase interactive design and the drag-and-drop (Figure 5.) The interface contained  
<sup>511</sup> the question prompt at the top of the screen. The options were presented in a list underneath the prompt. Survey  
<sup>512</sup> respondents could update the votes by selecting from a dropdown that provided all possible voting options and costs  
<sup>513</sup> given the number of credits available. A small summary box to the right of the interface showed the current total cost  
<sup>514</sup> and the remaining credits for the respondent. The interface randomly presented options to avoid ordering bias [71, 72].  
<sup>515</sup>

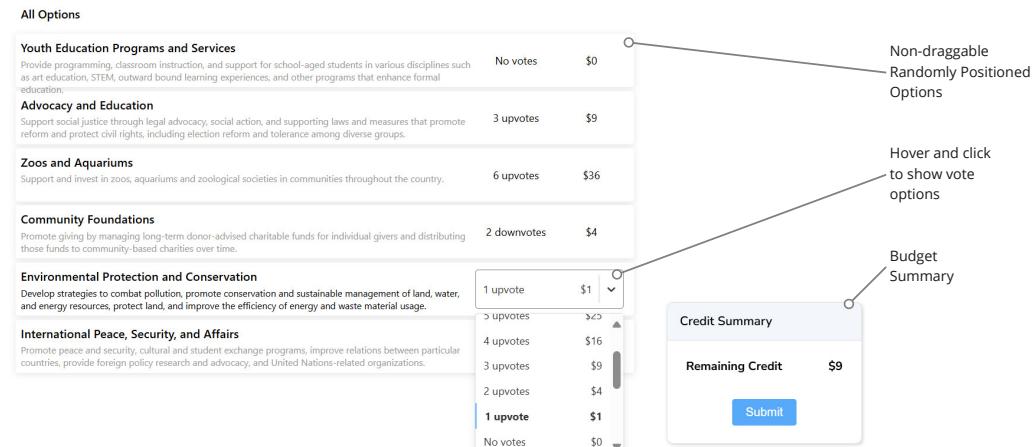
	Option	Rating	Cost
521	Voting Item Item description will be placed here	- +3 rating +	\$9
522	Voting Item Item description will be placed here		\$9
523	Voting Item Item description will be placed here		\$9

535 Fig. 4. Alternative vote control. The click-based design (upper) mirrors traditional vote control used in other QV interfaces, where  
 536 each click controls one vote. The wheel-based design (the latter two) allows control through both clicks and mouse wheel rotation.

### What societal issues need more support?

The local community government is seeking your input on how to distribute limited resources among various societal issues. Using the **quadratic survey mechanism**, please indicate your preferences below. *Upvote* more for issues you think deserve more resources, and *downvote* more for those you believe should receive fewer resources.

You have 59 credits to distribute. You can vote on each option by clicking the dropdown menu when you hover over the option.



562 Fig. 5. The text-based interface: This interface is based on the interactive version but does not include the two-phase interactive  
 563 support and lacks the drag-and-drop functionality. Options are randomly positioned.

567 Both experiment interfaces are developed with a React.js frontend and a Next.js backend powered on MongoDB. We  
 568 open-sourced both interfaces.<sup>1</sup>

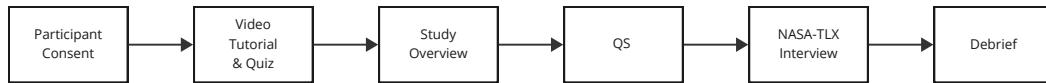
570  
 571 <sup>1</sup>[link-to-github](#)

**573 4 Experiment Design**

**574** In this section, we detail the experiment design and rationale for these decisions.

**575 4.1 Experiment Protocol**

**576** We recruited participants from a United States college town using online ads, digital bulletins, social media posts,  
**577** online newsletters, and physical flyers in public spaces beyond campus. To ensure participant diversity, we prioritized  
**578** non-students by selectively accepting them as we monitored demographics. The study was framed as focusing on  
**579** societal attitudes to avoid response bias. The university’s Institutional Review Board reviewed and approved this study.  
**580**



**581** Fig. 6. Study protocol: Participants are asked to learn about the mechanism of QS after consenting to the study. The researcher  
**582** explained the study overview and asked participants to complete the QS. A NASA-TLX survey followed by interviews to understand  
**583** participants’ cognitive load. We debriefed participants after the study.

**584** Figure 6 visually represents the study protocol. Participants completed the study in the lab to control for external  
**585** influences. Participants used a 32-inch vertical monitor displaying all options on the survey to prevent hidden information  
**586** during decision-making. After consenting, participants watched a video explaining the quadratic mechanism without  
**587** hints of interface operation followed by a quiz to ensure understanding. Participants rewatched the video or consulted  
**588** the researcher until they could select the correct answers. The participant’s screen was captured throughout the study.  
**589** The researcher primed the participant that the study aimed to help local community organizers understand preferences  
**590** on societal issues to better allocate resources. Participants were randomly assigned to one of four groups:  
**591**

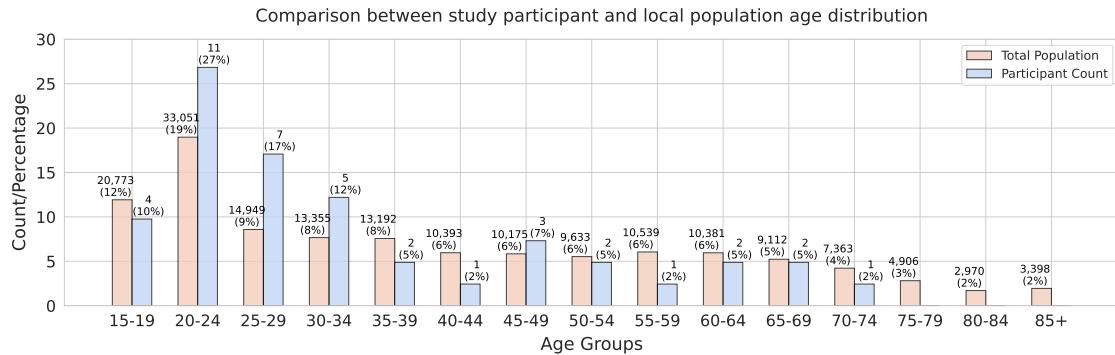
- 592** • ST: 6 societal issue options with a text-based interface
- 593** • SI: 6 societal issue options with a two-phase interface
- 594** • LT: 24 societal issue options with a text-based interface
- 595** • LI: 24 societal issue options with a two-phase interface

**596** Participants completed the survey independently, without the researcher’s presence. They then contacted the  
**597** researcher for the NASA-TLX survey, followed by a short audio-recorded semi-structured interview. The session  
**598** concluded with a debriefing and a \$15 cash compensation, during which participants were informed of the study goal  
**599** on cognitive load and interface design.

**600** We made several experimental design choices. First, we selected a between-subject design to minimize study fatigue,  
**601** considering the complexity of QS, and avoiding the learning effect that could influence how participants evaluated  
**602** the options. Second, we chose the context of public resource allotment for societal issues, following the methodology  
**603** from Cheng et al. [3]. These issues are relevant to all citizens and effectively demonstrate the need to prioritize limited  
**604** public resources. We curated 26 societal issues used by Charity Navigator [73] which evaluates over 20,000 charities in  
**605** the United States. The interface randomly presents options from this list to participants. Appendix C contains the full  
**606** list.

We relied on prior literature to test 6 and 24 options, representing short and long lists, as identifying the ‘breaking point’ for cognitive overload would require impractical time and resource commitments. Constant sum surveys and the Analytic Hierarchy Process (AHP) recommend fewer than ten and seven options, respectively [74, 75, 76]. Miller [77]’s classic work on cognitive processing capacity and Saaty and Ozdemir [78]’s theoretical proof supported the use of  $7 \pm 2$  items. A meta-analysis by Chernev et al. [79] identified 6 and 24 as common values for short and long lists in choice overload studies, rooted in the original experiment by Iyengar and Lepper [54].

Finally, we deployed self-report subjective surveys and analytical measures (i.e., time and clickstream data). We adopted the paper-based weighted NASA Task Load Index (NASA TLX), a widely used multidimensional tool that averages six subscale scores to represent overall workload after completing a task [80, 81, 82]. NASA-TLX is favored for its low cost and ease of administration [83], with less variability compared to one-dimensional workload scores [84], making it suitable for our study. While cognitive load can be measured through performance measures, psychophysiological measures, subjective measures, and analytical measures [83], given the extended nature of QS we chose not to adopt them.



(a) Age distribution of the participants skewed slightly younger despite following similar trends as the county population.



(b) Gender distribution of our participants skewed slightly towards female participants.

(c) Ethnicity distribution remains diverse with slightly less Hispanic and African American participants.

Fig. 7. Demographic distributions: Age, Gender, and Ethnicity

## 677 5 Cognitive Load and Sources across Experiment Conditions

678 This section presents cognitive load across experiment groups and the sources contributing to each cognitive load  
 679 dimension. Due to the smaller sample size, we focus on descriptive statistics and qualitative assessments. We present  
 680 quantitative data from survey tasks and qualitative insights from post-survey interviews.

682 To analyze the qualitative data, the first author conducted an inductive thematic analysis process [85] after transcribing  
 683 the interview. They coded snippets from each transcript based on specific research questions and topics of interest for  
 684 the qualitative analysis. Similar codes were merged within each research question or topic to form relevant themes.  
 685 When differences were hypothesized, they applied a deductive coding process to text snippets related to a specific  
 686 research question or topic of interest.

688 The results for this section are organized as follows: we start with participant demographics and then provide an  
 689 overview of our cognitive load findings. We then examine the six dimensions used in the NASA-TLX survey: mental  
 690 demand, physical demand, temporal demand, performance, effort, and frustration.

### 694 5.1 Demographics

695 We recruited a total of 41 participants, with one excluded due to data quality concerns, resulting in ten participants  
 696 per experimental condition.<sup>2</sup> The mean participant age was 34.63 years old, with an age distribution similar to the  
 697 county's demographic profile (Figure 7a) albeit a slightly higher representation of younger adults, particularly in the  
 698 35-45 range. As shown in Figure 7b, the majority of participants skewed toward females. Regarding ethnicity, 51.2% of  
 699 the participants identified as White, 26.8% as Asian, 7.3% as African American, and 4.9% as Hispanic. Additionally, 9.8%  
 700 of participants reported mixed ethnicity.

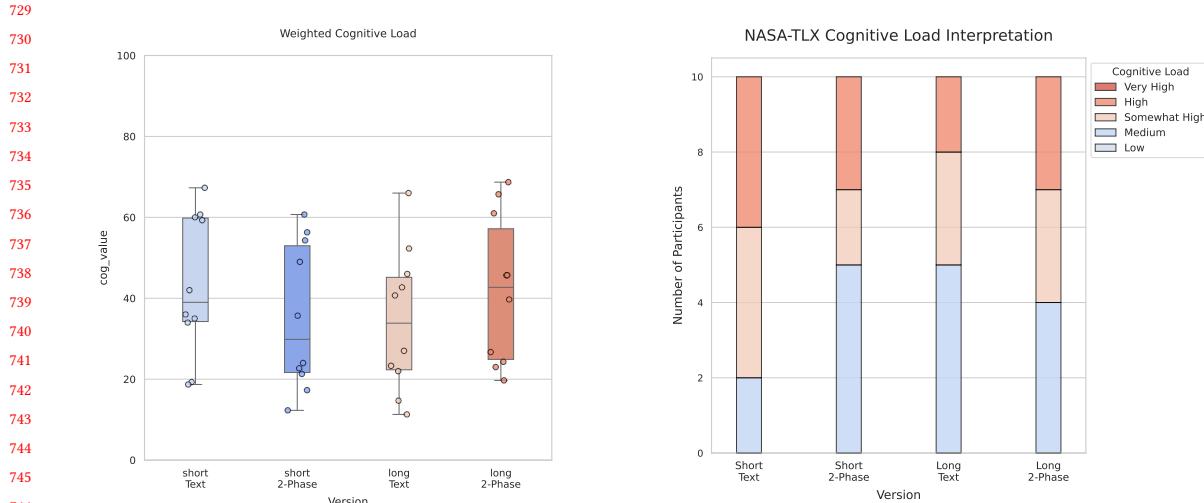
### 705 5.2 Overall Cognitive Load

706 To answer RQ1 and RQ2a, we derive the weighted NASA-TLX scores across the four experiment conditions. We show  
 707 these results in Figure 8. Weighted NASA-TLX uses a continuous 0-100 score, with higher values indicating greater  
 708 cognitive load. We use predefined mappings of NASA-TLX scores to cognitive levels: low, medium, somewhat high,  
 709 high, and very high, as listed by Hart and Staveland [80]. We show value interpretations in Figure 8b.

710 Surprisingly, the long text interface had lower mean ( $\mu = 34.60$ ) and median ( $\tilde{x} = 33.85$ ) cognitive load scores than  
 711 both the short text ( $\mu = 43.23$ ,  $\tilde{x} = 39.00$ ) and long interactive interfaces ( $\mu = 42.02$ ,  $\tilde{x} = 42.70$ ). Additionally, the  
 712 two-phase interface decreased cognitive load for the short survey but increased it for the long survey. Notably, the  
 713 short text interface had the most participants ( $N = 8$ ) reporting somewhat high or higher cognitive loads, whereas the  
 714 other conditions had a more balanced distribution, with about half reporting medium to high loads.

715 We acknowledge that these results may not fully reflect actual cognitive load due to noise from factors like small  
 716 sample size, task nature, or participants' interpretation of the cognitive load scale. To explore these possibilities further,  
 717 we turn to qualitative insights from post-task interviews.

722  
 723  
 724  
 725  
 726 <sup>2</sup>The participant reported not completing the survey seriously because they believed the experiment was fake.



(a) NASA-TLX Weight Score: The Long Two-Phase Interface exhibits the highest weighted cognitive load with a median of 42.70, a mean of 42.02. This is higher than the Long Text Interface, which has a median cognitive load of 33.85, a mean of 34.60. However, the Short Text Interface demonstrates a higher cognitive load with a median of 39.00, a mean of 43.23, compared to the Short Two-Phase Interface which has a median of 29.85, a mean of 35.36. Standard deviation are similar across groups at around 18.

(b) NASA-TLX Cognitive Interpretation: More participants in the Short Text Interface, totaling 8, reported a somewhat high or above cognitive load, which is significantly higher compared to the 5 participants who reported similarly for the Short Two-Phase Interface. However, the Long Two-Phase Interface saw slightly more participants, 6 in total, reporting somewhat high or above cognitive load compared to the Long Text Interface.

Fig. 8. This figure shows the box plot results for weighted NASA-TLX scores across experiment groups and participant counts based on individual score interpretations. In 8a, we observe a downward trend in cognitive load for the short QS, while the long QS shows an upward trend. Interestingly, there is a counterintuitive downward trend between short and long text interfaces. In 8b, these trends are clearer when NASA-TLX scores are grouped into five tiers.

### 5.3 Sources of Mental Demand

**Key Differences:** First, slightly more participants using the text interface reported mental demand from precisely determining the number of votes for options compared to the two-phase interface. Second, when it comes to long QS, participants using the long two-phase interface considered broader societal impacts and evaluated options holistically, while those in the long text interface focused on personal relevance and individual issues.

Mental demand refers to the degree of mental and perceptual activity required to complete a task. Interview results showed primary drivers of participants' mental demand were *Budget management* and *Preference construction*<sup>3</sup>.

5.3.1 *Mental Demand Source #1: Budget management.* 14 participants expressed demand from budgeting within limited credit (S032 [...] for certain societal issues you had to ... take away from other societal issues that you could support., N = 5), tracking remaining credits (S006 [...] looking at the remaining

<sup>3</sup>The full table is in Appendix D.1.

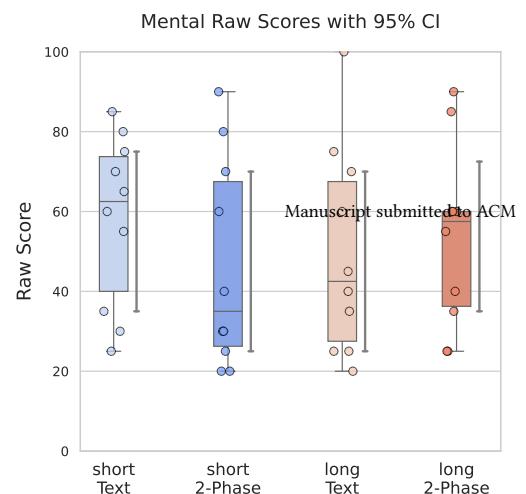


Fig. 9. Mental Demand Raw Score: Across all four

<sup>781</sup> credits, I'm trying to mentally divide that up before I start allo-  
<sup>782</sup> cating , N = 10), and maximizing credit use ( S032 ↗ [...] I  
<sup>783</sup> used all the credit that I had available , N = 8).

<sup>784</sup>

<sup>785</sup> We categorized budget management-induced mental de-  
<sup>786</sup> mand as operational (single interface-level action, e.g., using  
<sup>787</sup> the last remaining credit) or strategic (higher-level goal, e.g.,  
<sup>788</sup> evenly distributing credits across options). Long survey par-  
<sup>789</sup> ticipants more often report operational causes suggesting that  
<sup>790</sup> more survey options induced short-term thinking.

<sup>791</sup>

<sup>792</sup>

<sup>793</sup> 5.3.2 *Mental Demand Source #2: Preference construction.* All  
<sup>794</sup> but one participant reported increased mental demand due to  
<sup>795</sup> preference construction. We further break it down into three  
<sup>796</sup> sources: comparative preference evaluation (i.e., evaluating  
<sup>797</sup> relative importance between options; S002 ↗ Figuring out  
<sup>798</sup> ... how much I prioritize option 1 over option 2 , N = 16), resource-constraint prioritization (i.e., trading off between  
<sup>799</sup> options due to resource constraints, S005 ↗ [...] very hard to take decisions ... because I felt that multiple options deserve  
<sup>800</sup> equal amount of credit ... but you have given very limited amount of credit . , N = 17), and precise resource allocation (

<sup>801</sup> S023 ↗ [...] having to pick how many upvotes would go to each one , N = 30).

<sup>802</sup>

<sup>803</sup>

<sup>804</sup> Almost all participants mentioned preference construction as a source of mental demand, supporting the theory that  
<sup>805</sup> preference construction is a difficult and mentally demanding task. Notably, more participants using the text interface  
<sup>806</sup> reported mental demand from precise resource allocation compared to the two-phase interface (18 vs. 12). We conjecture  
<sup>807</sup> that the first pass on the survey items in the organization phase helped participants reduce their mental demands in  
<sup>808</sup> this area once they got around to vote allocation.

<sup>809</sup>

<sup>810</sup>

<sup>811</sup> In addition, when categorizing preference construction-induced mental demand, participants (N = 8) in the long text  
<sup>812</sup> interface tend to consider a smaller scope that focuses on personal relevance. Conversely, participants (N = 9) in the  
<sup>813</sup> long two-phase interface considered the broader societal impact and evaluated options more comprehensively. Compare  
<sup>814</sup> the following two quotes, where one focused on adjusting credits between two options and the other reflecting across  
<sup>815</sup> broader societal values:

<sup>816</sup>

<sup>817</sup> Trying to figure out what upvotes I should give [...] I kind of went back and forth between those two. [...] So it was very mentally  
<sup>818</sup> tasking for me.

↗ S015 (LT)

<sup>819</sup>

<sup>820</sup>

<sup>821</sup> [...] really having to think, especially with so many different societal issues. How do I personally prioritize them? And to what extent  
<sup>822</sup> do I prioritize them?

↗ S009 (LI)

<sup>823</sup>

<sup>824</sup>

<sup>825</sup> Inspecting both causes, while we did not notice significant differences in mental demand raw values (Figure 9)  
<sup>826</sup> across the four experiment groups, especially between the interfaces across long QS, they exhibited different sources  
<sup>827</sup> contributing to their mental demand.

## <sup>828</sup> 5.4 Sources of Physical Demand

<sup>829</sup>

<sup>830</sup> ↗ **Key Differences:** Two-phase interface experienced higher physical demand from increased mouse usage.

Physical demand refers to the physical effort required to complete a task, such as physical exertion or movement. Most participants reported minimal physical demand ( $N = 32$ ), reflected in the low NASA-TLX physical demand scores (Figure 10). Notably, 11 out of 20 participants who used the two-phase interface mentioned physical demand from using the mouse, reflecting their increased interaction with the interface. This is further supported by the raw NASA-TLX physical demand scores (Figure 10), which show a significant visual difference between short and long two-phase interfaces as well as between text and two-phase interfaces in long surveys.

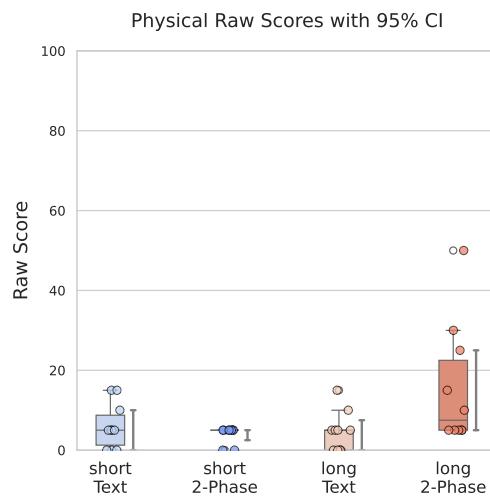


Fig. 10. Physical Demand Raw Score: Participants other than the long two-phase interface reported minimal physical demand. The long two-phase interface had the highest physical demand, likely due to increased mouse clicks and extended time spent looking at the vertical screen.

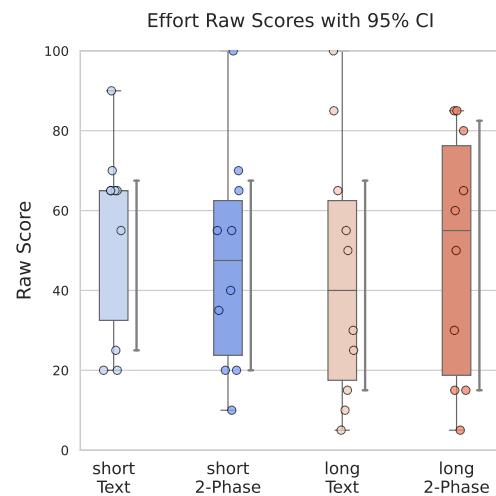


Fig. 11. Effort Raw Score: Effort scores shows indifference across groups.

Table 1. Effort Sources: Participants using the text interface focused more on operational tasks, while those using the two-phase interface focused more on strategic planning.

[ Effort ]	Total	Version				Experiment Conditions				
		ST	SI	LT	LI	Short	Long	Text	Inter	
<b>Operational</b>	21	6	5	8	2	11	10	14	7	1
<b>Strategic</b>	28	6	8	5	9	14	14	11	17	1
Personal	22	4	7	5	6	11	11	9	13	1
Global	11	2	3	2	4	5	6	4	7	1
<b>None/Little/a bit</b>	9	2	1	3	3	3	6	5	4	1

885           **5.5 Source of Effort**

886           **Q Key Differences:** First, participants in the text interface associated effort with operational tasks more often  
 887 than participants from the two-phase interface. Conversely, participants in the two-phase interface cited more  
 888 sources from strategic planning than those in the text interface. We observed that participants experienced effort  
 889 when considering a comprehensive view while using the two-phase interface.  
 890

891           Effort refers to how hard participants felt they worked to achieve the level of performance they did. Since effort  
 892 includes both mental and physical resource intensity, refer to Section 5.3 and Section 5.4 for definitions.  
 893

894           While the raw NASA-TLX effort scores (Figure 11) showed a similar spread across experiment groups, the qualitative  
 895 analysis showed more distinction that participants using the two-phase interface considered options more comprehensively  
 896 and felt less effort on completing operational tasks, similar to what we found on mental demands (Section  
 897 5.3).  
 898

899           **5.5.1 Effort Source #1: Operational Tasks.** 14 of the 20 participants using the text interface mentioned Operational  
 900 Tasks as effort sources, compared to 7 using the two-phase interface, with the lowest mention by the long two-phase  
 901 interface group ( $N = 2$ ).  
 902

903           **5.5.2 Effort Source #2: Strategic Planning.** Different from Operational Tasks, 11 participants in the text interface  
 904 compared to 17 participants described strategic planning as sources of effort, with almost all participants ( $N = 9$ ) from  
 905 the long two-phase interface. We further categorize strategic planning into *narrow* and *broad* scopes as we did for  
 906 mental demand section 5.3. Participants using the two-phase interface ( $N = 7$ ) had nearly mentioned double ( $N = 4$ )  
 907 times regarding global strategies.  
 908

909           **5.6 Sources of Temporal Demand**

910           **Q Key Differences:** First, participants using the short text interface wanted to complete the task quickly and  
 911 reported the highest temporal demand. The two-phase interface lowered the temporal demand for short QS. Second,  
 912 participants using the long text interface showed the lowest temporal demand score. The two-phase interface  
 913 increased the temporal demand for long QS.  
 914

915           Temporal demand measures the time pressure participants feel during a task. Lower demand indicates participants  
 916 felt comfortable taking a more leisurely pace. We categorize the main sources of increased temporal demand as the time  
 917 pressure on *Decision Making* (S024 *Q maybe I should just hurry up and make a decision.*,  $N = 15$ ) and *Operational Tasks* (S032  
 918 *Q to be able to move through this quickly and efficiently*,  $N = 16$ ) (Table 5). *Budget* also came up occasionally (S034  
 919 *Q as the money decreases I felt kind of rushed*,  $N = 4$ ).  
 920

921           **5.6.1 Two-phase Interface Reduced Temporal Demand on Short QS.** The raw NASA-TLX values in Fig 12 show that  
 922 participants in the Short Text Interface condition reported the highest temporal demand among all. They framed  
 923 concerns as time spent on making decisions. Five participants felt they invested more time and effort than anticipated,  
 924 prompting them to rush. The two-phase interface reduced this, with only one participant in the short survey group  
 925 reporting similar concerns.  
 926

**5.6.2 Long QS on Text Interface Showed the Lowest Temporal Demand.** Based on the raw NASA-TLX values in Fig 12, participants in the long text interface exhibited the lowest temporal demand, explaining why this group had the lowest overall cognitive load as discussed in Section 5.2. This is counter-intuitive since participants in this condition made more decisions and operations compared to the short text group. There are two potential explanations. First, we noticed that more participants who experienced a short survey expressed a desire to complete the task efficiently ( $N = 7$ ) than those in the long survey groups ( $N = 1$ ). They often expressed things like:

I wanna get through things in an efficient manner [...] to move through this quickly and efficiently.  S032 (ST)

A second possible explanation for the unexpectedly low temporal demand in the Long Text condition was the participants' satisficing behaviors.

I didn't really do the math, so I was like \$2 is not that much left so I tried my best to use up most of it.  S035 (LT)

Due to cognitive overload from the long list of options, participants may have spent less time than they expected on the decisions. We will discuss this possibility in-depth in Section 7.1.

**5.6.3 Two-phase Interface Increased Temporal Demand in Long QS.** Despite the unexpectedly low temporal demand in long QS with a text interface, completing the long QS with our two-phase interface raised the temporal demand to the level of short QS groups. All five participants who mentioned a feeling of time pressure on decision-making in the Long Two-phase group described the pressure affirmatively. This means their pressure stemmed from having too many remaining decisions to make ( S022  So it didn't take too much time, but obviously there was a lot of things to consider, so there was some temporal demand. ), not from the time they have already spent (i.e., framed negatively) as that in the Short Text group.

## 5.7 Source of Frustration

 **Key differences:** We observed evidence that participants in the long text interface showed the least amount of frustration from operational causes compared to other experiment conditions.

Frustration refers to the extent to which the participant is annoyed, irritated, or discouraged during the task.

Sources of frustration were generally related to either *Operational Actions* (e.g., credit management ( $N = 6$ ) and managing quadratic vote costs ( $N = 5$ )), or *Societal Concerns* (e.g., regretful tradeoffs ( $N = 8$ ) or pessimism about other's vote ( $N = 6$ )). We provide the full table in Appendix D.5.

In general, the frustration derived from societal concerns did not seem strongly affected by any of the experimental conditions. With respect to operational action-driven frustration, however, we saw some discrepancies. The long text interface condition had the fewest participants expressing operational frustration, with half expressing no frustration,

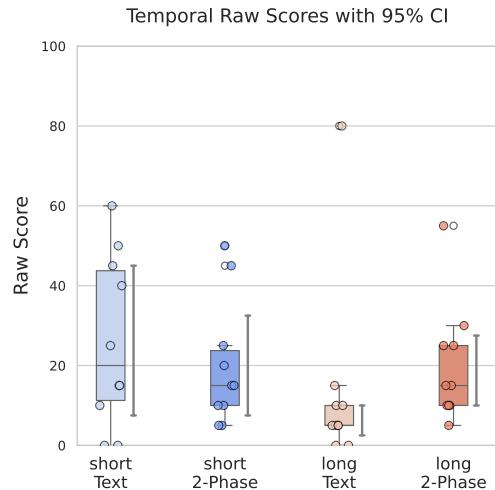


Fig. 12. Temporal Demand Raw Score: The short text interface results in the highest temporal demand, while the long text interface is the lowest. Two-phase interfaces show moderate temporal demand, suggesting that interactive elements allowed participants to pace themselves better.

989 mirroring the trends in the actual scores (Figure 13). Similar to the finding that the long text group has the lowest  
 990 temporal demand, this is counter-intuitive as more options and dense text are known to lead to more frustration in  
 991 interface design. Participants engaging in satisficing behaviors in the long text interface may explain this phenomenon  
 992 – prior literature [86, 87] indicates that satisficers tend to be less frustrated and happier than maximizers.  
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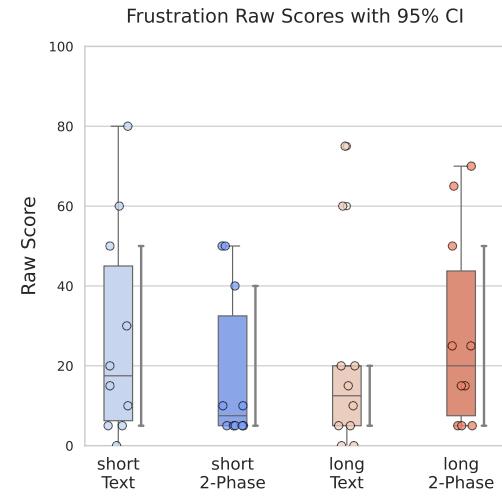
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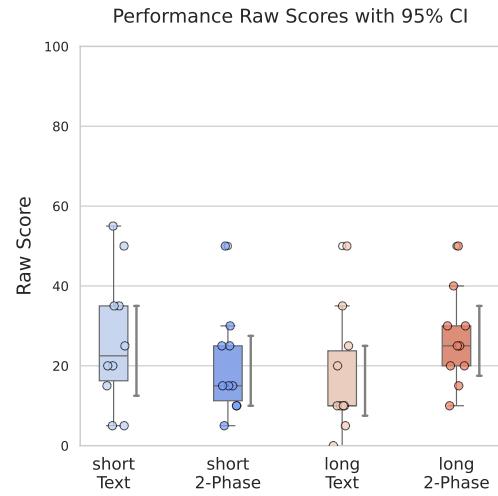
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1013 Fig. 13. Frustration Raw Score: Participants other than  
 1014 the long text interface highlighted several operational  
 1015 tasks that led to frustration. All groups share causes  
 1016 from strategic planning.



1013 Fig. 14. Performance Demand Raw Score: Participants  
 1014 showed indifferent performance raw scores across exper-  
 1015 iment conditions, all trending toward satisfactory.

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## 5.8 Source of Performance

**Key Differences:** Participants who used a two-phase interface were generally more positive about their final outcome – they were twice as likely to report "feeling good" about their final results

Performance refers to a person's perception of their success in completing a task. Lower values mean good perceived performance; higher values mean poor perceived performance. We found minimal qualitative differences between experiment groups regarding factors influencing perceived performance. Two influencing factors emerged: *Operational Actions* and *Social Responsibility*<sup>4</sup>. Despite most participants reporting positively on their performance, nuances exist in how different groups interpret their performance.

**5.8.1 Operational Actions.** Operational actions, like the theme presented in temporal demand, refer to specific, executable procedures participants perform in the survey. This could involve: pressure to spend all credits or stay within budget ( $N = 6$ ), fears that final vote choices did not reflect true preferences ( $N = 5$ ), or concerns that they had finished the task inefficiently ( $N = 6$ ).

<sup>4</sup>The full performance table is at Appendix D.3

1041     5.8.2 *Social Responsibility.* Social responsibility-based concerns around performance came up when participants  
 1042 reflected on how their final vote counts would be perceived by others ( S041 *I don't want people to think that I just*  
 1043 *like don't care about <ethnicity> people at all* ) or influence real-world decision-making ( S027 *Some of these things*  
 1044 *might ... have outcomes that I didn't foresee* ).

1045     All groups cited social responsibility as source to evaluate effort. Raw NASA-TLX scores (Figure 14) show participants  
 1046 had indistinguishable performance scores. This aligns with the interview results where most participants felt positive  
 1047 about their final submission.  
 1048

1049     To dig deeper, we also analyzed participants' language when they described their performance. Expressions like  
 1050 "good enough" may be indicative of satisficing behaviors – our results suggest participants are satisfied at similar rates  
 1051 regardless of the interface. 1/4 of the participants in the text interface expressed "done their best," referring to exhausting  
 1052 their effort. Participants who used a two-phase interface were generally more positive about their final outcome – they  
 1053 were twice as likely to report "feeling good" about their final results ( $N = 11$  v.s.  $N = 6$ ).  
 1054

## 1055     5.9 Summary across all cognitive load dimensions

1056     In this subsection, we gathered differences across dimensions and synthesized them into a list.  
 1057

- 1058       • **Mental Demand:** Participants using the text interface reported higher mental demand from determining the  
     1059 number of votes for options. Those using the long two-phase interface considered broader societal impacts and  
     1060 evaluated options holistically.
- 1061       • **Physical Demand:** Physical demand was higher for participants using the two-phase interface due to increased  
     1062 mouse usage.
- 1063       • **Effort:** Effort sources varied, with text interface participants focusing more on operational tasks, and two-phase  
     1064 interface participants engaging more in strategic planning, reflecting deeper, more comprehensive consideration  
     1065 of options.
- 1066       • **Temporal Demand:** Temporal demand was highest in the short text interface, where participants aimed to  
     1067 complete tasks quickly, while the long text interface showed the lowest temporal demand.
- 1068       • **Frustration:** Frustration levels from operational causes were lowest in the long text interface.
- 1069       • **Performance:** Participants using the two-phase interface felt more positive about their performance, being  
     1070 twice as likely to report "feeling good" about their results compared to the text interface users.

1071     Overall, participants using the two-phase interface tend to think more comprehensively and critically, while those  
 1072 using the text interface focus more narrowly on operational tasks. In addition, we suspect that participants who  
 1073 completed the long QS on a text interface engaged in satisficing behaviors based on the counter-intuitive results that  
 1074 they had the lowest temporal demand and frustration level. We will interpret these results in the discussion section. To  
 1075 better understand participants' behavior, we analyze click-stream data across experiment conditions in the next section.  
 1076

## 1077     6 Behavior Results

1078     To answer RQ3, we investigate time-to-action and remaining credit differences across experiment conditions. Time-to-  
 1079 action is a widely used metric in decision sciences, where longer decision time often indicates more complex cognitive  
 1080 processing [88]. Additionally, resource allocation strongly influences decision making. Cheng et al. [3] showed that the  
 1081 number of given credits influences the validity of QV. Decision science studies like Shah et al. [89] and [90] showed  
 1082

1093 how scarcity influences decisions, increases risk aversion, and adds cognitive load. These measures serve as proxies for  
1094 participant behavior, and all analyzed data is publicly available<sup>5</sup> for transparency and to facilitate further research.  
1095

### 1096 6.1 Time Spent per Option

1098 Our first analysis focuses on understanding how much time participants spent per option across different stages and  
1099 experiment conditions. Based on the QS system log, we can derive the following detailed logs of participant actions: *the*  
1100 *option* involved in the interaction, *the type of interaction* (such as updating a certain number of votes), and *the time*  
1101 between this interaction and the previous one.  
1102

1103 We aggregate all the time spent on each option as the total time spent for that option. Organization time covers both  
1104 placing options into categories and the drag-and-drop time during the organization phase. Voting time strictly refers to  
1105 the time participants took to update vote values for each option. To minimize noise, we intentionally drop all the time  
1106 participants spent on the first option in the organization phase or voting phase. The goal is to exclude time spent on  
1107 reading the prompt, forming their preference, or understanding the interface.  
1108

1109 Figure 15 each dot represents one option for one participant. Figure 15a shows total time, figure 15b shows organization  
1110 time, and figure 15c shows voting time. The violin plot shows the distribution of the dots and the three horizontal lines  
1111 represent the median, 25th percentile, and 75th percentile of the time spent for that interface. We limited the y-axis to 1  
1112 minute to improve visualization clarity.  
1113

1114 Participants spent slightly more time per option on the two-phase interface than the text interface. A non-parametric  
1115 Mann-Whitney U test showed a small effect size (long QS:  $p < 0.0000001$ , Rank-biserial:  $-0.304$ , Cohen's d:  $-0.030$ ; short  
1116 QS:  $p = 0.01$ , Rank-biserial:  $-0.37$ , Cohen's d:  $-0.082$ ). This is expected as the two-phase interface has an additional  
1117 step of organizing the options. We break down the total time spent into organization time and voting time in Figure 15b  
1118 and Figure 15c.  
1119

1120 We observed minimal difference in organization time per option (Figure 15b) between short and long surveys,  
1121 as options are shown one at a time for drag-and-drop. In terms of the voting time (Figure 15c), participants spent  
1122 significantly less time voting on the two-phase interface than on the text interface with a small effect size in the long QS  
1123 ( $U = 24053, p < 0.005$ , Rank-biserial:  $0.167$ , Cohen's d:  $0.017$ ), but not in the short survey ( $p > 0.4$ , Power=0.051). This  
1124 supports our hypothesis that the two-step design in the two-phase interface facilitates more efficient decision-making,  
1125 especially in longer surveys.  
1126

### 1127 6.2 Budget and Voting Behaviors

1128 To further analyze participant behaviors, we break down the aggregated time from the previous analysis and examine  
1129 fine-grain interactions. Specifically, we examine if there are differences among behavior across interfaces. As we  
1130 outlined, credit scarcity might influence decision making. Figure 16 plots the time of voting actions over the remainder  
1131 of the participant's budget across the text and two-phase interface across all four groups. Each bar shows the number  
1132 of actions accumulated across participants at specific percentages of remaining credits. A kernel density estimate (KDE)  
1133 plot is provided to visualize the trends. We did not follow Quarfoot et al. [5] in counting accumulated votes over time  
1134 due to varying total times across individuals.  
1135

1136 Comparing experiment groups, we see fewer differences in the short QS but different interaction distributions  
1137 between the two interfaces in the long QS. Given the significant differences in voting time between the text and  
1138

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1139<sup>5</sup>link-to-github

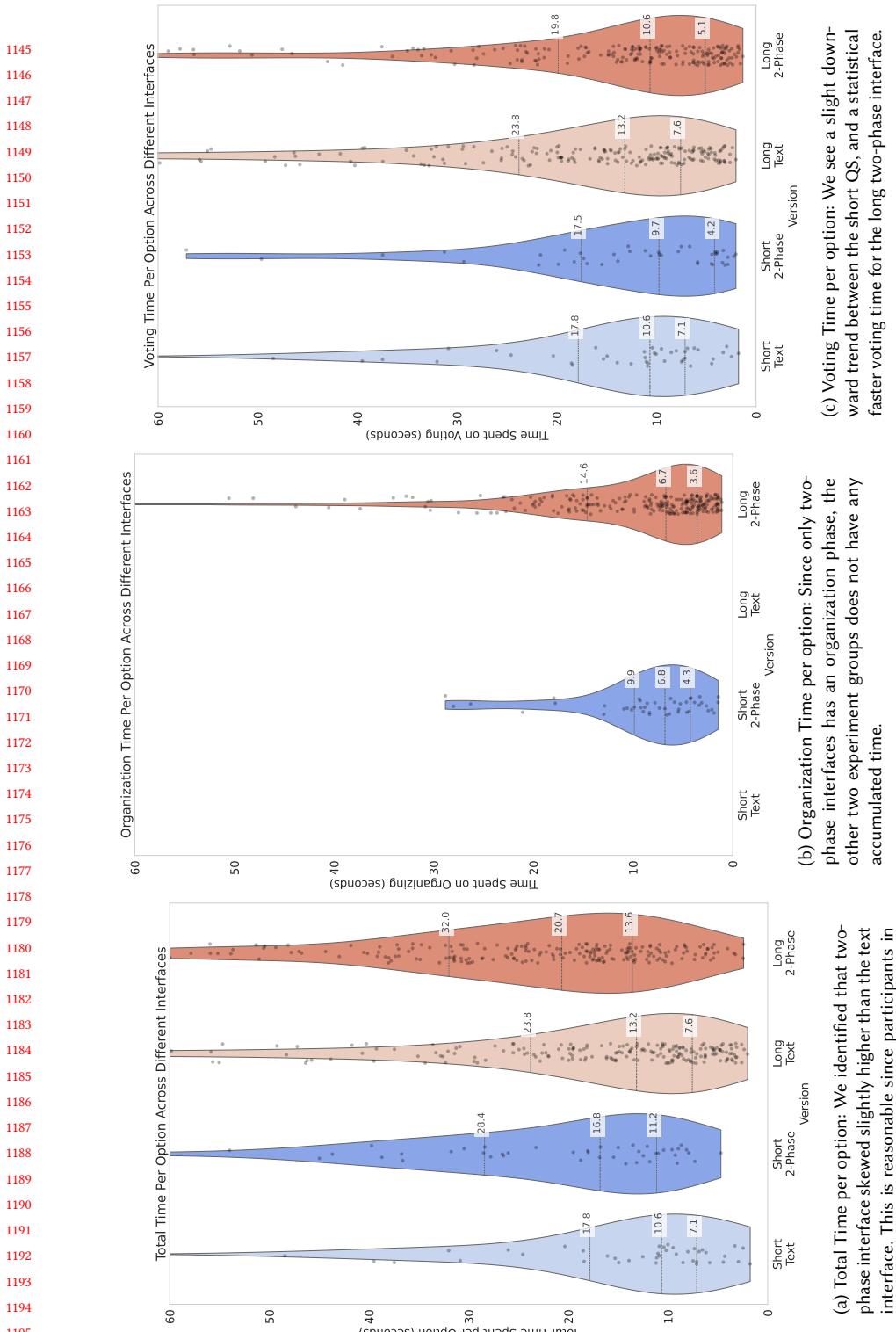


Fig. 15. Time per option across all experiment conditions. In each of these violin plots, a dot represents the total time a participant spent on that option. Fig. 15a one dot represents the total time a person spent for one option. Figure 15b and Figure 15c are decomposition of the total time.

(a) Total Time per option: We identified that two-phase interface skewed slightly higher than the text interface. This is reasonable since participants in these two conditions require additional time to complete the organizing steps.

(b) Organization Time per option: Since only two-phase interfaces has an organization phase, the other two experiment groups does not have any accumulated time.

(c) Voting Time per option: We see a slight downward trend between the short QS, and a statistical faster voting time for the long two-phase interface.

<sup>1197</sup> two-phase interface for the long QS, we focus on deciphering the voting action changes between these two conditions  
<sup>1198</sup> in this subsection.  
<sup>1199</sup>

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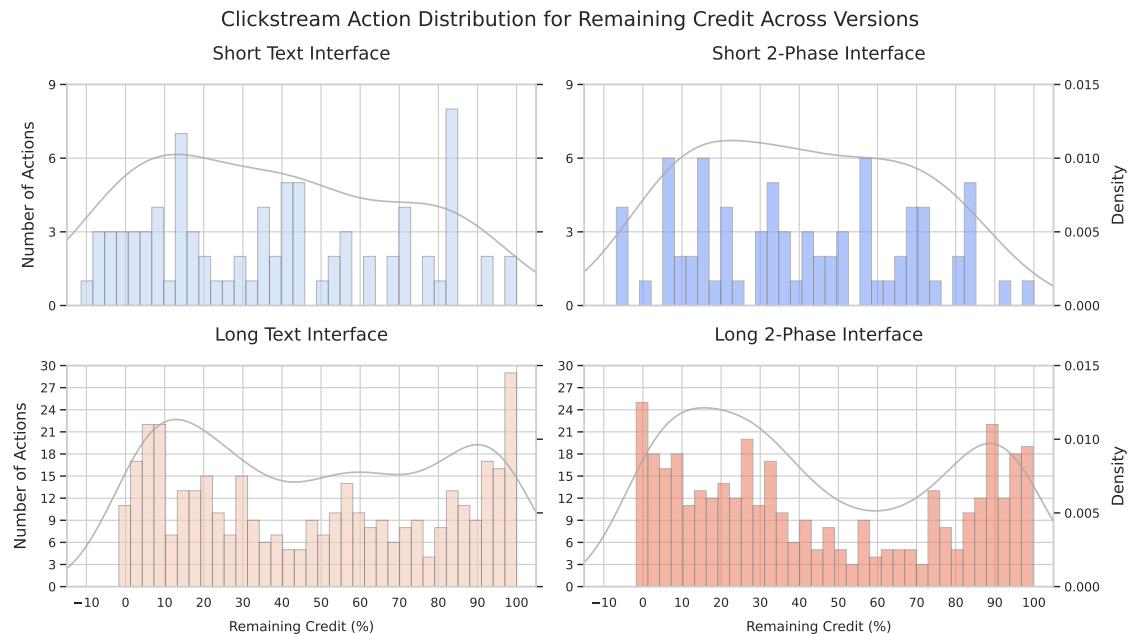


Fig. 16. This plot counts the number of voting actions when there are  $x$  percentages of credits remaining. A KDE plot is provided to help better understand the action distribution.

In Figure 16, we see two distinct patterns between the short survey and the long survey in terms of participant behaviors. In long surveys, participants exhibited more actions both when the budget was abundant and when it began to run out. This pattern was more pronounced with the long two-phase interface. We further separated the behaviors where participants made large or small changes to the options, specifically for the long version. In Figure 17, we define an adjustment of four or more votes as large, which we plotted in the first row of the figure. Adjustments of two or fewer votes are considered small, which is 10% of the possible values one can choose among the maximum of 21 votes.

We plotted all actions against the time to complete them. Revisiting the KDE curve in the second row in Figure 16 and the curve of the second row in Figure 17 show a stronger bimodal distribution for small vote adjustments across interfaces. In fact, the bimodal distribution is more pronounced in the two-phase interface. This suggests that participants make small adjustments both at the beginning and toward the end of the QS. However, the two-phase interface shows more frequent and faster edits towards the end. Visually, dots are more clustered in the long two-phase interface for small vote adjustments compared to the long text interface. The Mann-Whitney U Test on the time spent on small vote adjustments showed significant differences ( $U = 13037, p < 0.001$ ), with a small effect size (Rank-biserial: 0.227, Cohen's d: 0.195) and a power of 0.381. Based on the KDE plots in the first row of Figure 17, participants also made more large vote adjustments early on that spread more equally compared to the text interface. This indicates that participants had a clearer idea of how to distribute their credits across the options.

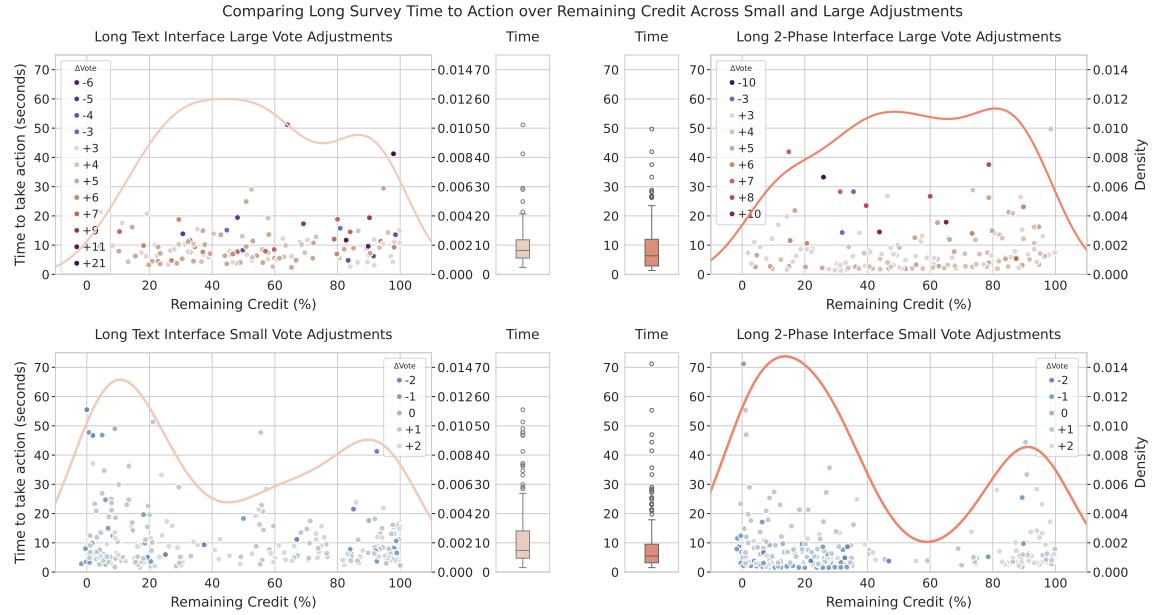


Fig. 17. This plot further separates participants' interaction behavior based on the number of votes participants adjusted. We observed a bimodal interaction pattern across long QS when small vote adjustments are made.

In interviews, five participants highlighted the importance of the interface's flexibility and their use of an incremental, iterative approach. All these participants used the two-phase interface. While this doesn't mean participants using the text interface didn't take an iterative approach, it highlights that the two-phase interface encouraged iterative and incremental updates. As one participant pointed out:

*I like the fact that it remembers everything that you know [...] that's very important is that it's an iterative process. ↗ S019 (LI)*

To summarize, participants spent more time on the two-phase interface compared to the text interface in both short and long surveys. Across the two-phase interfaces, organization time remained consistent. While voting time did not differ between interfaces for the short survey, participants voted more quickly on the two-phase interface in the long survey, confirming the hypothesis that the two-step design enhances decision-making efficiency. Voting behaviors indicated more frequent actions when the budget was abundant and nearly exhausted, particularly in the long two-phase interface. Additionally, the analysis revealed more frequent and faster small vote adjustments towards the end of the QS in the two-phase interface, demonstrating an iterative and incremental approach.

## 7 Discussion and Future Works

This study proposed a two-phase interface for QS to study how the number of survey options and interfaces influence cognitive load and behavior in social resource allotment context. Section 5 and 6 revealed that longer surveys did not increase cognitive load, contrary to expectations.

In the discussion section, we interpret results related to cognitive load and survey respondent behaviors. We focus on three key topics: what two-phase interface elements influenced behavior, how these elements supported preference

1301 construction, and remaining design challenges. Additionally, we provide recommendations for using QS and suggest  
1302 design improvements.  
1303

1304 We concluded that the two-phase interface prevented satisficing behaviors and promoted more strategic, holistic  
1305 thinking, unlike the text-based interface, which leans more toward operational tasks. Behavioral analysis showed that  
1306 long two-phase interface participants made frequent, small updates, shifting their cognitive load focus.  
1307

### 1308 7.1 Interpretation of results: Two-phase interface limits satisficing during cognitive overload

1310 Participants using the long two-phase interface reported slightly higher cognitive load compared to those using the  
1311 long text interface. In comparison, the short two-phase interface resulted in a lower cognitive load. This suggests that  
1312 the two-phase interface alone does not inherently increase cognitive load.  
1313

1314 One explanation is that the two-phase interface reduces cognitive load in the short QS but not in the longer one. In  
1315 longer surveys, the interactive nature of the two-phase interface may require participants to perform more operations  
1316 without significantly altering their decision-making processes. However, our findings suggest that participants using  
1317 the two-phase interface in longer surveys responded more efficiently. Across both short and long surveys, participants  
1318 using the two-phase interface demonstrated iterative and efficient fine-tuning preferences, indicating deeper survey  
1319 engagement. Therefore, we reject the claim that the two-phase interface increases cognitive load in the long survey.  
1320

1321 An alternative explanation is that while the two-phase interface limits satisficing during cognitive overload, the  
1322 complexity of the long QS may have counteracted this effect, preventing a full reduction in cognitive load. This suggests  
1323 that long QS participants resorted to satisficing behaviors to manage their cognitive overload. Qualitative results support  
1324 this explanation: participants using the two-phase interface engaged in broader, more strategic considerations, while  
1325 those using the text interface focused on operational tasks. For instance, participants using the long two-phase interface  
1326 experienced less cognitive burden from precise voting and managed their time better. Overall, the two-phase interface  
1327 participants demonstrated deeper and more critical thinking, as they engaged in more strategic decision-making.  
1328

1329 In contrast, participants using the long text interface satisficed due to cognitive overload from having to decide  
1330 and allocate more credits for more options. However, fewer participants in this group reported high cognitive load  
1331 compared to those in the short-text interface. This group also experienced the least temporal demand and frustration  
1332 with operational tasks, despite spending a similar amount of time per option as participants using the text interface.  
1333 These counterintuitive findings pointed to the remaining plausible explanation that long-text interface participants  
1334 used satisficing to manage the overload.  
1335

1336 **In summary**, the interactive components of the two-phase interface likely prevented mental shortcuts [53, 9, 10,  
1337 11], resulting in a cognitive *shift* towards deeper reflection and decision-making. Thus, while QS with many options  
1338 might lead to satisficing, the two-phase interface redirects participants' attention, facilitating the decision-making  
1339 process that promotes comprehensive preference construction. In the following section, we examine these specific  
1340 elements that guided participants to achieve this.  
1341

### 1342 7.2 Bounded rationality and interface design

1343 Bounded rationality emerged as a core theme in participants' responses, highlighting how cognitive limitations lead to  
1344 sub-optimal decision-making due to their inability to process all available information [9]. This often led to *satisficing*  
1345 behaviors, where participants settle for *good enough* but not *optimal* decisions [91].  
1346

1347 For instance, S036 described making meaningful choices while acknowledging the limits of their effort:  
1348

1353 [...] you thought of enough things, you know, and so it wasn't the most effort I could put in because again, that would have been  
 1354 diminishing returns. I tried to think of enough things [...] and then move on. [...] I felt like that (the response) was satisfied, but not  
 1355 perfect. Cause perfect is not a reality.  S036 (ST)

1356  
 1357 This illustrates typical satisficing decision-making, where participants settle for suboptimal choices. In long QS, the  
 1358 significant increase in decision points—due to the numerous vote and credit options—was so overwhelming to some  
 1359 that even features like pre-calculated vote-credit values in drop-down menus provided relief, as they helped avoid the  
 1360 cognitively demanding task of searching for bounds.

1361  
 1362 Participants often relied on *heuristics* [92] and *defaults* [64], behaviors less common among two-phase interface  
 1363 participants. Presenting one option at a time reduced reliance on defaults and encouraged deeper reflection, as illustrated  
 1364 by S013, who highlighted how the organization phase supported their option preferences construction:

1365  
 1366 [...] it (organization phase) gives you time to just focus on that single thing and rank it based on how you feel at that moment.  
 1367  S013 (SI)

1368  
 1369 Conversely, text interface participants, like S003, described how default placements influenced their decisions:

1370  
 1371 Honestly, if medical research [...] was the first one I saw, I think it would automatically give it a lot more.  S003 (ST)

1372  
 1373 The three key elements of the organization phase—presenting options one at a time, grouping them into categories,  
 1374 and enabling drag-and-drop—worked together to structure participant preferences. These elements aligned with  
 1375 cognitive strategies like *problem decomposition* [93] and *dimension reduction* which reduces cognitive overload. Bounded  
 1376 rationality illuminates the importance of decision-making support interfaces rather than being a critique of human  
 1377 behaviors. One participant explained how the organization phase broke down complex decisions into manageable steps:

1378  
 1379 [...] being able to have a preliminary categorization of all the topics. First, it introduced me to all the topics, [...] to think about  
 1380 and process [...] being able to digest all the information prior to actually allocating the budget or completing the quadratic survey.  
 1381  S009 (LI)

1382  
 1383 Participants using the two-phase interface, especially in the long version, organized options along dimensions such  
 1384 as topics (e.g., health vs. humanitarian) and preferences (positive vs. negative) before voting. Others expressed that  
 1385 the upfront introduction of all options and the ability to rank and group them helped manage their cognitive load  
 1386 effectively. In contrast, almost half of the participants using the long text interface, like S028, expressed a desire for  
 1387 features that can help reduce the decision space when responding to the QS, further supporting the importance of these  
 1388 organizational design elements:

1389  
 1390 Because with this many (options), especially when I'm thinking ... Ok, where was (the option)... Where was (the option) you know?  
 1391 Oh, that's right. Maybe I could give another up another upvote to the, you know whatever [...]  S028 (LT)

1392  
 1393 This quote reflected participants' need to manually track and revisit options, which occupies cognitive load, without  
 1394 a more structured interface.

1395  
 1396 **In summary**, individual's bounded rationality encouraged participants to exhibit *satisficing* behaviors, *heuristics*,  
 1397 and *defaults* when responding to QS. Showing all options upfront, one at a time, and repositioning options based on partic-  
 1398 ipants' rough preferences prevented participants from using defaults and heuristics. The two-phase organization actively  
 1399 scaffolds participants' decision-making process, supporting efficiency *problem decomposition* and *dimension reduction*.  
 1400 Together, these elements in the two-phase interface design prevented *satisficing* behaviors and supported participants  
 1401 in making more informed decisions through a more strategic planning and holistic thinking process.

### 1405 7.3 Construction of Preference on QS

1406 Completing QS is a series of difficult decision tasks Lichtenstein and Slovic [6]. Svenson [60]’s differentiation and  
 1407 consolidation theory helps explain how participants process these decisions. The decision process begins with dif-  
 1408 ferentiation, where participants identify differences and eliminate less favorable options, followed by consolidation,  
 1409 which strengthens their commitment to selected choices. This theory aligns with how the two-phase interface helps  
 1410 participants decompose options into categories, effectively reducing decision complexity.  
 1411

1412 Participants started by constructing preferences in situ, especially regarding options they hadn’t previously consid-  
 1413 ered:

1414 [...] ‘Oh, there are other aspects that I never care about.’ And actually ... some people care <an option>. Sure. Why? Why (should) I  
 1415 spend money on that?

1416 S037 (LI)

1417 Those using the text interface, lacking the interactive tools, found it challenging to facilitate differentiation as S025  
 1418 noted:

1419 I would like to be able to like, click and drag the categories themselves so I could maybe reorder them to like my priorities. [...] make  
 1420 myself categories and subcategories out of this list ... If I could organize it.

1421 S025 (LT)

1422 In contrast, the two-phase interface allowed participants to express at least one dimension of differentiation more  
 1423 easily. The drag-and-drop feature helped blend this differentiation into the consolidation phase. Not only does partic-  
 1424 ipants drag-and-drop options post voting to reflect and assure a correct vote allocation, it also enables participants,  
 1425 like S039, to make fine-grain comparisons between options:

1426 I think the system was actually really helpful because I could just drag them. [...] I can really compare them, I can drag this one up  
 1427 here, and then compare it to the top one [...]

1428 S039 (SI)

1429 The bi-modal behavior observed in the long interactive interface participants provided in the results aligns with the  
 1430 differentiation and consolidation framework. Participants in the two-phase interface began differentiating options earlier  
 1431 allowing them to later adjust fine-grain votes. The faster and smaller vote updates indicated participants consolidating.  
 1432 The less prominent bi-modal behavior from the long text interface participants implied that the interface guided this  
 1433 decision framework as participant 037 explained:

1434 I only start from the positive one [...] I finish everything ... and then I move to the second part (the neutral box). [...] I want to focus  
 1435 on these and make sure that resources are at least they get the attention they want. And if there’s surplus and they can move to the  
 1436 second part.

1437 S037 (LI)

1438 These evidences explain how the organization phase and the drag-and-drop features supported differentiation and  
 1439 consolidation, scaffolding a decision-making framework enabling deeper engagement.

1440 **In summary**, participants construct their preferences as they complete QS. We observed behaviors and qualitative  
 1441 insights that align with the differentiation and consolidation theory in decision-making. Our interface scaffolded many  
 1442 of the differentiation stages through pre-voting organization and some consolidation phases through drag-and-drop,  
 1443 explaining how the two-phase approach supports preference construction to yield effective QS responses.

### 1444 7.4 Opportunities for better budget management

1445 Budget management is a recurring theme in participant interviews. While they appreciated the automatic calculation  
 1446 feature in modern QV interfaces, we identified three challenges for future QS interfaces: *cognitive load, the cold-start*  
 1447 *problem, and navigating between budget, votes, and outcome.*

1457    7.4.1 *Automatic calculation is critical.* Over one-third of participants ( $N = 14$ ) from all four experiment conditions  
 1458    emphasized the importance of automated calculation for deriving costs and tracking expenditures. For example:

1459    I thought I have [...] (to) do all the numbers or calculations myself as a part of checking my ability of doing mathematics. [...] I said  
 1460    that credit summary to be very specific. The credit summary section was really wonderful in doing all the calculations on that end.  
 1461    ↗ S005 (LT, keeping track of spent)

1462    The quotes marked the importance that QS must be facilitated by computer-supported interfaces.

1463    7.4.2 *The coldstart problem.* We notice from the study that one of the biggest challenges for participants is deciding  
 1464    'how many votes' to start with. This challenge pertains to the initial vote, not the relative vote. Some participants began  
 1465    by equally distributing their credits to all options and then made adjustments. Others established 1, 2, and 3 votes as  
 1466    starting points. A small handful surprisingly used the tutorial's example of 4 upvotes as their anchor.

1467    This arbitrary voting decision echoes discussions in prior literature about the existence of an absolute value for  
 1468    individuals. Coherent arbitrariness [94], similar to the anchoring effect in marketing, refers to participants' willingness  
 1469    to allocate votes, which can be influenced by an arbitrary value. However, the ordinal utility remains intact among the  
 1470    set of preferences.

1471    7.4.3 *Navigating Between Budget, Votes, and Actual Impact.* The third challenge is participants' confusion between  
 1472    budget, votes, and outcomes, despite understanding their definitions. One participant stated:

1473    [...] get rid of the upvote column or just get rid of the word upvote and just really focus on the money column. Listen. You're an  
 1474    organization or your participant. You have X amount of dollars you need to. You can only distribute X amount of dollars to these  
 1475    causes. So you have to figure out which ones get the most, which ones don't get as much. [...]

1476    Interviewer: [...] Do you feel that the more votes you're giving to a cause you're actually spending more on it?

1477    Yeah.

1478    ↗ S003 (ST)

1479    Participants like S003 bypassed the quadratic formulation, directly translating votes to resource allocation. While this  
 1480    does not invalidate the power of the quadratic mechanism, it causes frustration and friction for participants to construct  
 1481    a clear picture of how to make voting decisions. Future interfaces should better communicate these relationships to  
 1482    facilitate respondents' trade-offs.

1483    **In summary**, while the interface supports budget management through automated cost calculation, participants still  
 1484    face cognitive load from managing the budget. The cold-start problem and the confusion between budget, votes, and  
 1485    actual impact are open questions for future research. These challenges highlight the need for better budget management  
 1486    support to complete the QS interface.

## 1487    7.5 Quadratic Survey Usage, Design Recommendations and Future Work

1488    With a deeper understanding of how survey respondents interact with QS and the sources of cognitive load, we  
 1489    recognize that while this current interface may not significantly reduce cognitive load, it represents a crucial step  
 1490    toward constructing better interfaces to support individuals responding to QS. In this subsection, we outline usage  
 1491    and design recommendations applicable to all applications using the quadratic mechanism and highlight directions for  
 1492    future work.

1493    7.5.1 *Usage Recommendation: QS for Critical Evaluations.* Our study highlighted the complex cognitive challenges  
 1494    and in-depth consideration required when ranking and rating options using QS, even in a short survey. Similar to  
 1495    survey respondents needing to make trade-offs across options, researchers and agencies seeking additional insights and

1509 alignment with respondent preferences must ensure that survey respondents have the cognitive capacity to complete  
1510 such surveys rigorously. QS should be designed for critical evaluations, such as investment decisions, or situations  
1511 where participants have ample time to think and process the survey. For instance, revealing the options ahead of time  
1512 can aid in preference construction.  
1513

### 1514 7.5.2 Design Recommendations.

1515 *Use Organization Phases for Quadratic Mechanism Applications.* Our study demonstrated that preference construction  
1516 can shift from operational to strategic and higher-level causes. An additional organizational phase with direct  
1517 manipulation capability allows survey respondents to engage in higher-level critical thinking. We believe this approach  
1518 should extend beyond QS to other ranking-based surveying tools, such as rank-choice voting and constant sum surveys.  
1519 Further research should examine how implementing such functionality alters survey respondents' mental models.  
1520

1521 *Facilitate Differentiation through Categorization, Not Ranking.* Participants in our study were less inclined to provide  
1522 a full rank unless necessary. The final 'rank' of option preferences often emerged as a byproduct of their vote allocation,  
1523 constructed in situ. Therefore, for survey designs to be effective in constructing preferences, it is more important to  
1524 facilitate differentiation than to focus on direct manipulation solely for fine-tuning. Emphasizing categorization can  
1525 better support participants in articulating their preferences.  
1526

1527 7.5.3 *Future Work: Support for Absolute Credit Decision.* Deciding the absolute amount of credits in QS is highly  
1528 demanding. Designing interfaces and interactions that address the cold start challenge and help participants decide the  
1529 absolute vote value while considering ways to limit direct influences remains an open question. Future research should  
1530 explore innovative solutions to support participants in making these complex decisions effectively.  
1531

1532 By implementing these recommendations and pursuing future research directions, we can improve the usability and  
1533 effectiveness of QS and other quadratic mechanism-powered applications, ultimately aiding respondents in making  
1534 more informed and accurate decisions.  
1535

## 1536 8 Limitations

1537 Evaluating the QS interface is challenging due to its novelty. During the study, we identified several limitations that  
1538 require further research.  
1539

1540 *Understanding results influence on decision-makers.* Further research is required to understand how the QS interface  
1541 impacts decision-makers and broader societal resource distributions. Since QS is still in its early stages, we prioritize its  
1542 widespread adoption and usage before attempting a comprehensive assessment of its influence on decision-making.  
1543 Future studies will examine how decision-makers interpret and use QS data, as well as its broader implications for  
1544 societal decisions.  
1545

1546 *Individual differences in cognitive capacity.* Variations in individual cognitive capacity influenced participants' cog-  
1547 nitive scores. For example, participants with more experience in decision-making might be able to manage multiple  
1548 options more effectively. A within-subject study could clarify cognitive load shifts, but deconstructing established  
1549 preferences and altering options further complicates this. Thus, we opted for this in-depth, between-subject study,  
1550 although the small sample size may introduce noise that distorts the actual cognitive load. Future research should  
1551 quantify the impact of different QS interfaces.  
1552

Limited experience with QS. Participants had no prior experience with the QS interface. Following a tutorial and quiz, participants proceeded to complete tasks using the QS interface. While participants understood the QS mechanics, familiarity with the interface still influences strategies and cognitive load. As quadratic mechanisms become more prevalent, future research can compare novices and experts.

Duration between clicks to represent decision-making. Click duration may include time spent considering other options, so it must be treated as an approximate measure of decision-making time. For instance, deciding between two options may take longer for the first option and less time for the second. Despite its limitations, this approach provides valuable insights into decision-making within our experimental constraints.

## 9 Conclusion

Surveys enable decision-makers to aggregate crowd opinions. In this study, we use QS to elicit individual responses in the context of social resource allotment. After multiple design iterations, we propose an two-phase interface for QS. We then examined its influence on individuals' cognitive load and behaviors when faced with societal issues of varying lengths. In a 2x2 between-subject study, we had participants experience either a long or short QS using a text-based or two-phase interface. NASA-TLX questionnaires and interviews revealed that participants using the two-phase interface for a long QS demonstrated a more comprehensive and critical evaluation of societal issues, despite not experiencing a lower cognitive load. Participants using the long text interface experienced cognitive overload, which led to satisficing behaviors or mental shortcuts. Analyzing click-stream data, we identified that participants made fine-grain iterations using the long two-phase interface when credits were low. We demonstrate that a two-phase, organize-then-vote interface can scaffold the complex decision-making process, helping individuals express their opinions for collective societal decisions. Through the iterative design process and detailed interviews, we identified future directions and design recommendations for collective decision-making applications using the quadratic mechanism.

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## A Voting Interface Breakdown

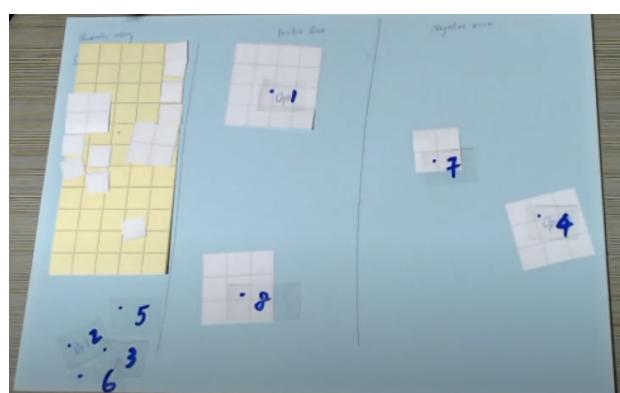
*Designs that shifted voter decisions:* For example, states without straight-party ticket voting (where voters can select all candidates from one party through a single choice) exhibited higher rates of split-ticket voting [12]. Another example from the Australian ballot showing incumbency advantages is where candidates are listed by the office they are running for, with no party labels or boxes.

**1769 Designs that influenced errors:** Butterfly ballots increased voter errors because voters could not correctly identify the  
**1770** punch hole on the ballot. Splitting contestants across columns increases the chance for voters to overvote [46]. On  
**1771** the other hand, Everett et al. [47] showed the use of incorporating physical voting behaviors, like lever voting, into  
**1772** graphical user interfaces.  
**1773**

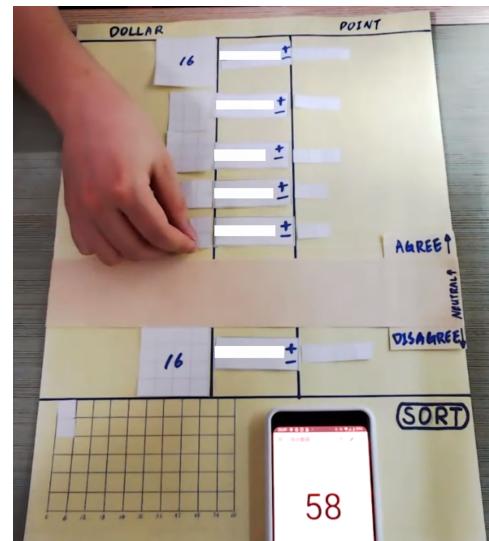
**1774 Designs that incorporated technologies:** Other projects like the Caltech-MIT Voting Technology Project have sparked  
**1775** research to address accessibility challenges, resulting in innovations like EZ Ballot [48], Anywhere Ballot [49], and  
**1776** Prime III [50]. In addition, Gilbert et al. [51] investigated optimal touchpoints on voting interfaces, and Conrad et al.  
**1777** [52] examined zoomable voting interfaces.  
**1778**

## **1780 B Interface design process**

**1782** In this section, we outline the design process leading to our final interface. As mentioned in the paper, our design  
**1783** iteration is based on existing QV applications in the wild.  
**1784**



**1805** (a) In this paper prototype, issues are denoted by different numbers that  
**1806** appear on mouseover. Pretest respondents can move options anywhere in  
**1807** the two sections of the interface, one denoting positive and one negative.  
**1808** The blocks represent the cost for each option, with no indication of the  
**1809** number of current votes. The credits are shown in the yellow box on the  
**1810** left.



**1811** (b) This paper prototype separates the positive and negative areas with a 'band' at the center. Undecided options  
**1812** are placed inside this band. The cost and the votes on  
**1813** both sides of the interface are denoted by small blocks.  
**1814** The budget is shown in the yellow box below the interface with a numerical counter.  
**1815**

Fig. 18. Initial paper prototypes designed for QS interface

**1816** *B.0.1 Prototype 1: Ranking-Vote.* Considering that relative preference is often through ranking items, we tested whether  
**1817** ranking options before voting would help establish an individual's relative preference in our prototype 1. This prototype  
**1818** allowed respondents to reposition options before voting. Pretests revealed that respondents rarely moved the options  
**1819** and questioned the necessity of full ranking, as it did not influence their QS submission. Additionally, many were  
**1820** unaware that options were draggable until shown. This insight indicates that full ranking is unnecessary for establishing

1821 relative preferences. Therefore, we decided to ask respondents to select a subset of options instead of requiring a full  
 1822 rank among all options.  
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### What societal issues need more support?

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Please express your opinion using this survey mechanism as described above. You have a total of \$324 for the following 9 issues. You do not need to use up all your budget, but you cannot exceed \$324.

If you think that an issue needs more support, you can rate the issue higher. Vice versa, you can rate the issue lower if you think it requires less support.

<input type="text" value="1"/>	<input type="button" value="+1 rating"/>	<input type="button" value="-1 rating"/>	Dots and Arrows (Animal Rights, Welfare, Art Services; Wildlife Conservation, Zoo and Aquariums)	Your ratings cost \$9 You rated this option +3
<input type="text" value="1"/>	<input type="button" value="+1 rating"/>	<input type="button" value="-1 rating"/>	Human Services (Childcare and Family Services; Youth Development, Shelters, and Crisis Services; Food Banks, Food Pantries, and Food Distribution; Multipurpose Human Service Organizations; Homeless Services; Social Services)	Your ratings cost \$16 You rated this option +4
<input type="text" value="1"/>	<input type="button" value="+1 rating"/>	<input type="button" value="-1 rating"/>	Arts, Culture, Humanities (Libraries, Historical Societies and Landmark Preservation; Museums, Performing Arts; Public Broadcasting and Media)	Your ratings cost \$4 You rated this option -2
<input type="text" value="1"/>	<input type="button" value="+1 rating"/>	<input type="button" value="-1 rating"/>	Education, Youth, and Community (Early Childhood Programs and Services; Youth Education Programs and Services; Adult Education Programs and Services; Special Education; Education Policy and Reform; Scholarship and Financial Support)	Your ratings cost \$16 You rated this option +6
<input type="text" value="1"/>	<input type="button" value="+1 rating"/>	<input type="button" value="-1 rating"/>	Environment (Environmental Protection and Conservation; Botanical Gardens, Parks and Nature Centers)	Your ratings cost \$4 You rated this option -2
<input type="text" value="1"/>	<input type="button" value="+1 rating"/>	<input type="button" value="-1 rating"/>	Healthcare (Diseases, Disorders, and Disabilities; Patient and Family Support; Treatment and Prevention)	Your ratings cost \$4 You rated this option -2

**Summary**

You have spent \$73 and you have \$251 remaining

1842 Fig. 19. A Ranking-Vote Prototype: The goal of this prototype is to test whether ranking options prior to voting help establish an  
 1843 individual's relative preferences and reduce effort when voting. Each option is draggable to position in a specific location amongst the  
 1844 full list of options. Votes can be updated using the buttons to the right of the interface with vote count and costs to the right of the  
 1845 interface. A summary box is placed sticky to the bottom of the screen.

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This is a playground designed to help you understand how to use Quadratic Survey.

There is a limited budget to purchase the food for dinner party tonight. Your friend is asking for your preference of the type of food to get for the dinner party tonight. Please complete the survey below.

Step 1: What is important to you?

In this step, please elect the options that you cared about to the left of the column.

All Options	Options You Care About
American	Italian
Japanese	Chinese
Mexican	

Step 1: What is important to you?

Step 2: Quadratic Voting

BACK TO STEP 1

You will be given a budget of a certain amount of dollars. You will use the available money to rate the options. If you think more resources should be allocated to a certain issue, you can rate the option higher using the +1. If you believe that less resources should be allocated on a certain issue, you can rate the option lower using the -1. If you are neutral on an issue, you can choose to not rate the option. You are allowed to rate the options positively or negatively.

Based on the intensity of your opinions, you can rate each issue positively and negatively. The stronger your opinion is, the higher the rating you can put on one option. Note that the cost of the ratings would increase quadratically. In other words, the cost of rating an issue cost  $X^2$  (square of X) dollars. The table shows the cost for ratings of 1-10 as an example. You can see that rating higher than 10 or lower than -10 the budget allows you to do so.

Rating	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
Cost in dollars against budget	1	4	9	16	25	36	49	64	81	100											

You cannot exceed the budget, but you do not have to use up all the budget either. You can see your total budget you have and the amount of dollars you have spent already in the "Summary" section below. The interface will provide real-time calculation of the remaining budget you have, the accumulated ratings the current options have received and the dollar spent for each option. The interface also provides a drag and drop feature to help you complete the survey.

<input type="text" value="1"/>	<input type="button" value="+1 rating"/>	<input type="button" value="-1 rating"/>	Chinese Orange chicken and rice	Your ratings cost \$4 You rated this option +2
<input type="text" value="1"/>	<input type="button" value="+1 rating"/>	<input type="button" value="-1 rating"/>	Italian Pasta and bread	Your ratings cost \$9 You rated this option -3
<input type="text" value="1"/>	<input type="button" value="+1 rating"/>	<input type="button" value="-1 rating"/>	American Burgers, fries and ribs	Your ratings cost \$0 You rated this option 0
<input type="text" value="1"/>	<input type="button" value="+1 rating"/>	<input type="button" value="-1 rating"/>	Japanese Sushi and udon	Your ratings cost \$0 You rated this option 0
<input type="text" value="1"/>	<input type="button" value="+1 rating"/>	<input type="button" value="-1 rating"/>	Mexican Tacos and burritos	Your ratings cost \$0 You rated this option 0

**Summary**

You have spent \$13 and you have \$37 remaining

(a) Options are dragged and dropped to the 'Option You Care About' box.

(b) The previous step collapses showing all voting options.

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Fig. 20. A Select-then-Vote Prototype: The goal of this prototype is to nudge participants to focus on a subset of options to vote, rather than ranking all of them. This prototype introduces a two-step voting process. As shown in Fig. 20a, the first step involves selecting options for further consideration. Important options are placed at the top of the list for voting shown in Fig. 20b, but options can be placed anywhere on the list if desired. The rest of the controls remain the same as the previous prototype.

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**B.0.2 Prototype 2: Select-then-Vote.** Based on feedback from Prototype 1, instead of *allowing* individuals to rank options, Prototype 2 implemented a two-phase process that *intentionally* asks respondents to select options to express opinions before voting. As shown in Figure 20, survey respondents selected their preferred options (Figure 20a), and the interface positioned these options at the top of the list for voting (Figure 20b). We identified several issues during the prototype 2 pretest: many respondents marked most options as ‘options they care about,’ which undermined the design’s purpose. Additionally, the lack of clear distinction between selected and unselected options confused respondents about the necessity of Step 1. Thus, we need a clearer distinction and connection between the two phases to effectively construct relative preferences.

What societal issues need more support?

Please express your opinion using this survey mechanism as described above. You have a total of \$324 for the following 9 issues. You do not need to use up all your budget, but you cannot exceed \$324.

If you think that an issue needs more support, you can rate the issue higher. Vice versa, you can rate the issue lower if you think it requires less support.

I don't know

- Pets and Animals (Animal Rights, Welfare, and Services; Wildlife Conservation, Zoos and Aquariums)
- Arts, Culture, and Media (Literature, Historical Societies and Landmark Preservation; Museums; Performing Arts; Public Broadcasting and Media)
- Health (Diseases, Disorders, and Disciplines; Patient and Family Support; Treatment and Prevention Services; Medical Research)
- Veteran (Wounded Troops Services; Military Social Services; Military Family Support)
- Education (Early Childhood Programs and Services; Youth Education Programs and Services; Adult Education Programs and Services; Special Education; Education Policy and Reform; Scholarship and Financial Support)
- Environment (Environmental Protection and Conservation; Botanical Gardens, Parks and Nature Centers)
- Humanitarian Relief (Development and Relief Services; International Peace, Security, and Affairs; Humanitarian Relief Supplies)
- Human Services (Child and Family Services; Youth Development; Shelters and Crisis Services; Food Banks; Food Pantries; and Food Distribution; Multipurpose Human Service Organizations; Homeless Services; Social Services)

Next

What societal issues need more support?

Please express your opinion using this survey mechanism as described above. You have a total of \$324 for the following 9 issues. You do not need to use up all your budget, but you cannot exceed \$324.

If you think that an issue needs more support, you can rate the issue higher. Vice versa, you can rate the issue lower if you think it requires less support.

I don't know

	+1 rating	-1 rating	Your ratings cost	You rated this option
Pets and Animals (Animal Rights, Welfare, and Services; Wildlife Conservation, Zoos and Aquariums)	+1 rating	-1 rating	\$4	+2
Arts, Culture, Humanities (Libraries, Historical Societies and Landmark Preservation; Museums; Performing Arts; Public Broadcasting and Media)	+1 rating	-1 rating	\$4	-2
Health (Diseases, Disorders, and Disciplines; Patient and Family Support; Treatment and Prevention Services; Medical Research)	+1 rating	-1 rating	\$4	+7
Veteran (Wounded Troops Services; Military Social Services; Military Family Support)	+1 rating	-1 rating	\$4	-2
Positive	+1 rating	-1 rating	\$0	0
Education (Early Childhood Programs and Services; Youth Education Programs and Services; Adult Education Programs and Services; Special Education; Education Policy and Reform; Scholarship and Financial Support)	+1 rating	-1 rating	\$0	0
Negative	+1 rating	-1 rating	\$6	-6
Neutral	+1 rating	-1 rating	\$0	0
Environment (Environmental Protection and Conservation; Botanical Gardens, Parks and Nature Centers)	+1 rating	-1 rating	\$4	-2
International (Development and Relief Services; International Peace, Security, and Affairs; Humanitarian Relief Supplies)	+1 rating	-1 rating	\$4	-2
Human Services (Child and Family Services; Youth Development; Shelters and Crisis Services; Food Banks; Food Pantries; and Food Distribution; Multipurpose Human Service Organizations; Homeless Services; Social Services)	+1 rating	-1 rating	\$0	0

Summary

You have spent \$117 and you have \$207 remaining

Back

Next

(b) The Voting Interface: Voting controls appear on the left side of each option, showing the current votes and associated costs on the right. A budget summary is stuck at the bottom of the screen.

(a) The Organization Interface: Options are shown initially in the first bin labeled as ‘I don’t know.’ Survey respondents can then drag and drop these options into the latter bins: Positive, Neutral, or Negative. Only the details of each option are shown on this interface.

Fig. 21. Organize-then-Vote Prototype: The goal of this prototype is to encourage participants at deriving finer grain categories among options before voting. Survey respondents first organize their thoughts into categories, then vote on the options.

**B.0.3 Prototype 3: Organize-then-Vote.** Figure 21 shows the last prototype where we built on the previous takeaway by providing finer-grain groupings and creating a clear connection between option organization and voting position. Specifically, we provided three categories: Positive, Negative, and Neutral. Initially, respondents see all options under the section labeled ‘I don’t know,’ which includes only the option descriptions. We ask respondents to move these options into the categories below. Voting controls and information appear on each option once respondents move to the subsequent page, forming a clear connection between option groups, positions, and voting controls.

Feedback indicated that survey respondents are comfortable with the two-phase organize-then-vote design, demonstrating it as a central strategy for our interface development. However, several areas for enhancement were identified:

1925 First, the dragging and dropping mechanism in the organization phase is cumbersome and may inadvertently suggest  
1926 a ranking process, contrary to our intentions. Second, placing unorganized options at the top of the voting list is  
1927 counterintuitive. Third, the voting controls are disconnected from the option summaries, dividing attention between  
1928 the left and right sides of the screen. These insights guided refinements in the final two-phase interface, adhering to the  
1929 two-phase organize-then-vote design framework.  
1930

## C List of Options

We provide the full list of options presented on the survey.

- 1934 • **Animal Rights, Welfare, and Services:** Protect animals from cruelty, exploitation and other abuses, provide veterinary services and train guide dogs.
- 1935 • **Wildlife Conservation:** Protect wildlife habitats, including fish, wildlife, and bird refuges and sanctuaries.
- 1936 • **Zoos and Aquariums:** Support and invest in zoos, aquariums and zoological societies in communities throughout the country.
- 1937 • **Libraries, Historical Societies and Landmark Preservation:** Support and invest public and specialized libraries, historical societies, historical preservation programs, and historical estates.
- 1938 • **Museums:** Support and invest in maintaining collections and provide training to practitioners in traditional arts, science, technology, and natural history.
- 1939 • **Performing Arts:** Support symphonies, orchestras, and other musical groups; ballets and operas; theater groups; arts festivals; and performance halls and cultural centers.
- 1940 • **Public Broadcasting and Media:** Support public television and radio stations and networks, as well as providing other independent media and communications services to the public.
- 1941 • **Community Foundations:** Promote giving by managing long-term donor-advised charitable funds for individual givers and distributing those funds to community-based charities over time.
- 1942 • **Housing and Neighborhood Development:** Lead and finance development projects that invest in and improve communities by providing utility assistance, small business support programs, and other revitalization projects.
- 1943 • **Jewish Federations:** Focus on a specific geographic region and primarily support Jewish-oriented programs, organizations and activities through grantmaking efforts
- 1944 • **United Ways:** Identify and resolve community issues through partnerships with schools, government agencies, businesses, and others, with a focus on education, income and health.
- 1945 • **Adult Education Programs and Services:** Provide opportunities for adults to expand their knowledge in a particular field or discipline, learn English as a second language, or complete their high school education.
- 1946 • **Early Childhood Programs and Services:** Provide foundation-level learning and literacy for children prior to entering the formal school setting.
- 1947 • **Education Policy and Reform:** Promote and provide research, policy, and reform of the management of educational institutions, educational systems, and education policy.
- 1948 • **Scholarship and Financial Support:** Support and enable students to obtain the financial assistance they require to meet their educational and living expenses while in school.
- 1949 • **Special Education:** Provide services, including placement, programming, instruction, and support for gifted children and youth or those with disabilities requiring modified curricula, teaching methods, or materials.

- 1977 • **Youth Education Programs and Services:** Provide programming, classroom instruction, and support for school-aged students in various disciplines such as art education, STEM, outward bound learning experiences, and other programs that enhance formal education.
- 1978 • **Botanical Gardens, Parks, and Nature Centers:** Promote preservation and appreciation of the environment, as well as leading anti-litter, tree planting and other environmental beautification campaigns.
- 1979 • **Environmental Protection and Conservation:** Develop strategies to combat pollution, promote conservation and sustainable management of land, water, and energy resources, protect land, and improve the efficiency of energy and waste material usage.
- 1980 • **Diseases, Disorders, and Disciplines:** Seek cures for diseases and disorders or promote specific medical disciplines by providing direct services, advocating for public support and understanding, and supporting targeted medical research.
- 1981 • **Medical Research:** Devote and invest in efforts on researching causes and cures of disease and developing new treatments.
- 1982 • **Patient and Family Support:** Support programs and services for family members and patients that are diagnosed with a serious illness, including wish granting programs, camping programs, housing or travel assistance.
- 1983 • **Treatment and Prevention Services:** Provide direct medical services and educate the public on ways to prevent diseases and reduce health risks.
- 1984 • **Advocacy and Education:** Support social justice through legal advocacy, social action, and supporting laws and measures that promote reform and protect civil rights, including election reform and tolerance among diverse groups.
- 1985 • **Development and Relief Services:** Provide medical care and other human services as well as economic, educational, and agricultural development services to people around the world.
- 1986 • **Humanitarian Relief Supplies:** Specialize in collecting donated medical, food, agriculture, and other supplies and distributing them overseas to those in need.
- 1987 • **International Peace, Security, and Affairs:** Promote peace and security, cultural and student exchange programs, improve relations between particular countries, provide foreign policy research and advocacy, and United Nations-related organizations.
- 1988 • **Religious Activities:** Support and promote various faiths.
- 1989 • **Religious Media and Broadcasting:** Support organizations of all faiths that produce and distribute religious programming, literature, and other communications.
- 1990 • **Non-Medical Science & Technology Research:** Support research and services in a variety of scientific disciplines, advancing knowledge and understanding of areas such as energy efficiency, environmental and trade policies, and agricultural sustainability.
- 1991 • **Social and Public Policy Research:** Support economic and social issues impacting our country today, educate the public, and influence policy regarding healthcare, employment rights, taxation, and other civic ventures.

## 2024 D Cognitive Demand Tables

2025 Here we provide the full qualitative analysis table.

2029 Table 2. This table lists all the causes participants mentioned as contributing to their Mental Demand. The shaded cells represent  
 2030 the percentage of participants citing each source of mental demand, allowing for comparison within columns. The abbreviations  
 2031 are: ST (Short Text Interface), SI (Short Two-phase Interface), LT (Long Text Interface), and LI (Long Two-phase Interface). Short and  
 2032 Long refer to the sum across both interfaces; Text and Inter refer to the sum across both survey lengths. We include Sparklines for  
 2033 comparisons across these experiment groups.

[ Mental Demand ]	Total	Version				Experiment Conditions			
		ST	SI	LT	LI	Short	Long	Text	Inter
<b>Budget Management</b>	14	3	3	5	3	6	8	8	6
Budget within limited credit	5	2	2	1	0	4	1	3	2
Track remaining credits	10	2	2	3	3	4	6	5	5
Maximize credit usage	8	2	3	2	1	5	3	4	4
Operational	12	3	2	4	3	5	7	7	5
Strategic	7	2	4	1	0	6	1	3	4
<b>Preference Construction</b>	39	10	9	10	10	19	20	20	19
Determining relative preference	16	4	4	5	3	8	8	9	7
Option prioritization	17	6	4	3	4	10	7	9	8
Precise resource allocation	30	9	6	9	6	15	15	18	12
Narrow - Consider a few options/personal causes	23	6	6	8	3	12	11	14	9
Broad - Considering all options or higher order values	23	5	5	4	9	10	13	9	14
<b>Demand from Experiment Setup</b>	24	6	6	6	6	12	12	12	12
Many options on the survey	6	0	0	3	3	0	6	3	3
QS Mechanism	4	2	0	2	0	2	2	4	0
Recalling experience or understanding options	20	5	6	4	5	11	9	9	11
<b>Justification or Reflection on response</b>	8	2	2	1	3	4	4	3	5
<b>External Factors</b>	12	3	1	4	4	4	8	7	5
<b>Demand due to Interface</b>	8	2	2	0	4	4	4	2	6
Increase	4	1	1	0	2	2	2	1	3
Decrease	4	1	1	0	2	2	2	1	3

2081 **D.1 Mental Demand Table**2082 **D.2 Physical Demand Table**

2083  
 2084  
 2085  
 2086  
 2087  
 2088 Table 3. Physical Demand Causes: Most participants expressed little or no physical demand. Results reflected that participants in the  
 2089 long two-phase interface required more actions, hence the higher mention of mouse usage as a source.

2091 [ Physical ]	Total	Version				Experiment Conditions			
		ST	SI	LT	LI	Short	Long	Text	Inter
2093 <b>Reading</b>	4	0	2	1	1	2	2	1	3
2094 <b>Mouse</b>	16	3	5	2	6	8	8	5	11
2095 <b>Vertical Screen</b>	4	1	0	1	2	1	3	2	2
2096 <b>None/Little</b>	32	8	9	8	7	17	15	16	16

2103 **D.3 Performance Table**

2104  
 2105  
 2106  
 2107  
 2108 Table 4. Performance Causes: Most causes are shared across experiment conditions. We provided qualitative interpretations of their  
 2109 own performance assessments.

2111 [ Performance ]	Total	Version				Experiment Conditions			
		ST	SI	LT	LI	Short	Long	Text	Inter
2113 <b>Operational Action</b>	13	2	3	3	5	5	8	5	8
2114    Budget Control	6	1	1	2	2	2	4	3	3
2115    Preference Reflection	6	1	1	2	2	2	4	3	3
2116    Limited Resources	5	1	2	1	1	3	2	2	3
2117 <b>Social Responsibility</b>	8	2	2	2	2	4	4	4	4
2118    Decision maker	7	1	2	2	2	3	4	3	4
2119    Outcome Uncertainty	7	1	2	2	2	3	4	3	4
2120 <b>Performance Assessment</b>									
2121    Did their best	8	2	1	3	2	3	5	5	3
2122    Feel Good	17	3	5	3	6	8	9	6	11
2123    Good Enough	10	2	2	3	3	4	6	5	5

2133 **D.4 Temporal Demand Table**

2134

2135 Table 5. Temporal Demand Sources: Decision-making and Operational Tasks are the main causes. Participants framed their decision-making sources differently.

2136

2138 [ Temporal ]	2139 Total	2140 Version				2141 Experiment Conditions			
		2142 ST	2143 SI	2144 LT	2145 LI	2146 Short	2147 Long	2148 Text	2149 Inter
<b>Budget Management</b>	4	0	1	1	2	1	3	1	3
<b>Decision Making</b>	15	5	2	3	5	7	8	8	7
Affirmative	9	0	2	2	5	2	7	2	7
Negative	8	5	1	2	0	6	2	7	1
<b>Operational</b>	16	5	6	3	2	11	5	8	8
Task completion	8	2	2	3	1	4	4	5	3
Being efficient	8	3	4	0	1	7	1	3	5

2152 **D.5 Frustration Table**

2153

2154 Table 6. Frustration Sources: needs to be updated with some new terms definitions for some of the columns.

2155

2156 [ Frustration ]	2157 Total	2158 Version				2159 Experiment Conditions			
		2160 ST	2161 SI	2162 LT	2163 LI	2164 Short	2165 Long	2166 Text	2167 Inter
<b>Strategic</b>	17	4	4	5	4	8	9	9	8
Higher-level	11	3	2	3	3	5	6	6	5
x Conflict between personal preference and broader society and common values	6	1	1	2	2	2	4	3	3
x Trade-offs among all options	8	3	1	2	2	4	4	5	3
Lower-Level	10	3	3	2	2	6	4	5	5
x Conflict between personal preference and broader society and common values	4	1	2	0	1	3	1	1	3
x Trade-offs among a few options	8	2	2	2	2	4	4	4	4
<b>Operational</b>	15	4	5	2	4	9	6	6	9
Credit management	6	2	3	1	0	5	1	3	3
Adhering to the Quadratic Mechanism	5	2	1	1	1	3	2	3	2
Deciding number of votes for an option	4	2	0	0	2	2	2	2	2
Making multiple decisions	3	2	0	0	1	2	1	2	1
Understanding Option	4	0	3	0	1	3	1	0	4
<b>None/Little</b>	16	4	5	5	2	9	7	9	7