

5-Step Approach to Designing Controlled Experiments

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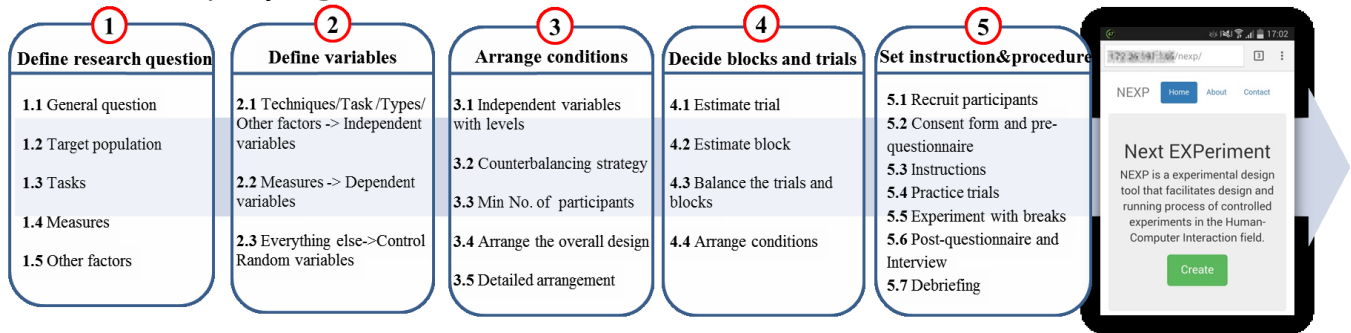


Figure 1. Panel 1-5 from left: the 5-step approach for designing a controlled experiment; NexP is a web-based experimental design tool that runs on both desktop computers and mobile devices. Panel 6 shows the starting page of the mobile interface of NexP.

ABSTRACT

Controlled experiment, an approach that has been adopted from research methods in psychology, is now widely used in HCI. Design an effective controlled experiment is not necessarily easy, even for experienced researchers. Existing controlled experiment designing tools focused more on the process of designing, but they are often not intuitive and guided enough for less experienced users to use. In this demo paper, we introduce NexP (Next Experiment Tool), a web-based open-source tool for designing controlled experiments. NexP introduces a 5-step approach to guide users through the experimental design process, and helped them to better understand the experimental design process, making it both a useful and educational tool.

Categories and Subject Descriptors

Human-centered computing ~ User studies

Author Keywords

NexP; Design Controlled Experiment; Experimental Design Tool

1. INTRODUCTION

Controlled experiments have been widely used in HCI to perform user evaluation, and help to understand cognition in the context where users are interacting with systems. Designing controlled experiments requires very concrete knowledge of the exact tasks, test conditions, and measures to complete. In addition, issues regarding the confounding factors and order effects require well planned in an experiment. Therefore, designing a reasonable controlled experiment can be difficult.

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To ease this designing process, researchers have proposed various tools [1] to facilitate experiment design. Existing tools mainly focus on the design process itself and help users to specify their design more easily once the design is more or less concretized. However, current tools are unable to provide much guidance to help users to start from a research question, and follow the scientific design process to come up with a viable design. There still remains the gulf execution among existing tools.

As a result, we designed and implemented NexP¹: a Next Experiment generating web-based open-source tool that directs the design of controlled experiments. In NexP, we aim to facilitate the gap between the initially rough research questions to a concrete design through a 5-step approach, allowing the users to think one step at a time to gradually narrow down the different aspects of experiment design, making the design process more intuitive and easy to follow. In addition, web-based NexP makes it easy to share the experimental design for verification and testing purposes.

2. THE 5-STEP APPROACH

The 5-step approach is formulated from the direct teaching experience of one of the co-authors, who taught Controlled Experiment Design in one of the HCI courses at local universities. A brief guideline for how to use the 5-step approach to design an experiment is illustrated in Figure 1. Basically, our approach divides the potentially complex experimental design process into 5 incremental steps: 1) Define research question; 2) Define variables; 3) Arrange conditions; 4) Decide blocks and trials; 5) Set instruction and procedure. Each step caters to a specific aspect of a concrete design to guide users from a rough initial idea to a detailed plan. The 5-step approach is implemented in our web-based tool NexP.

3. USING NEXP

We describe the steps of using NexP as follows. For ease of explanation, we use an example experimental design scenario from the literature [2] to walk through the steps. In this example,

¹ <http://www.nexp.site/>

the experimenter has come up with a new software keyboard layout called “Opti” and wants to compare it with the existing “QWERTY” soft keyboard layout.

Step One: To design the experiment using NexP, the experimenter first needs to concretize the general question s/he wants to test with (in this example: “How does the Opti layout compare with the QWERTY layout in terms of performance?”) into a testable hypothesis. To facilitate this process, NexP prompts the following template of hypothesis for the experimenter to fill in:

(Your solution/product/service) is better than (other solutions/products/services) in (what tasks) under (what contexts) based on (what measurable terms).

By filling in the corresponding field of the template, the experimenter forms a more complete hypothesis, as follows:

The “OPTI” keyboard is better than the “QWERTY” keyboard in typing the sentence “the quick brown fox jumps over the lazy dog” (task) under different screen sizes and different input devices (contexts) based on speed/accuracy (measures).

Step Two: Based on the formed hypothesis, NexP will map the different techniques/interfaces, types of task(s), and contextual factors into independent variables. It will also map the measures into dependent variables. In the “OPTI” vs. “QWERTY” experiment, NexP will suggest four independent variables: *technique, task, different screen sizes, and different input devices*. It will also suggest *speed and accuracy* as the two dependent variables. The experimenter can modify these variables (add, remove, rename) and add levels to each independent variable if needed. In this example, technique by default has two levels: “OPTI” vs. “QWERTY” layouts. For *screen size*, the experimenter added three levels (watch, mobile phone, and tablet), and for *input device*, the experimenter added two levels corresponding to finger touch and using a stylus as shown in Figure 2. Note that since task only has one level (typing the sentence “the quick brown fox jumps over the lazy dog”), NexP will recognize it as a controlled variable instead of an independent variable for the experiment.

Step Three: After the independent and dependent variables are determined, NexP guides the experimenter to arrange the conditions, as shown in Figure 2. The experimenter is prompted to make decisions for each independent variable on whether it is a between-subject or a within-subject factor. If within-subject is chosen, then NexP further asks the experimenter to determine the strategy to counterbalance the presentation order of the different levels of the factor. For counterbalancing strategies, NexP currently supports “Sequential,” “Random,” “Latin Square,” and “Fully Counterbalancing.” NexP provides a tutorial to explain the basic concept of *between-subject* and *within-subject* design and their trade-offs along with practical examples. In this example, the corresponding strategies chosen for each factor are: fully counterbalancing for *technique*, latin square for *screen size*, and fully counterbalancing for *input device*. Note that since both *technique* and *input device* have two levels, fully counterbalancing has the same effect as that of a latin square (Figure 2).

Step Four: Once the overall arrangement for the conditions is determined, NexP prompts the experimenter to enter information on the number of trials for each condition, the estimated time needed to complete each trial, and number of blocks in which the conditions are repeated. This information allows NexP to estimate the total amount of time needed to complete the experiment. Based on the calculation, the experimenter can then make adjustments to

the design decisions, such as counter-balancing strategies and the number of trials or blocks, to ensure the entire experiment is not too long or too fatiguing for the participants to complete.

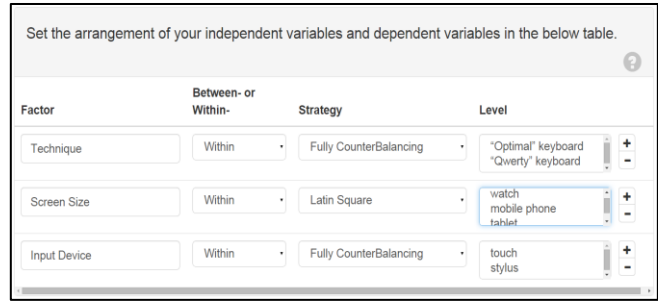


Figure 2. Setting the arrangement of the controlled experiment for each independent variable.

Once the entire design is determined, NexP allows the experimenter to examine the entire experiment arrangement for all participants in a simulation so that the design can be iteratively refined before deployment (Figure 3). The simulating results can be downloaded as a JSON file, which guides the experimenter to arrange and implement task trials for running the real experiment.

Step Five: Finally, NexP guides the experimenter to set the instructions and detailed procedures for conducting the experiment, such as recruiting participants, and provide consent forms. This step also provides support for the experimenter to design pre-/post- questionnaires using Google Forms and later invoke the designed questionnaires when running the experiment. The entire design can then be saved as a summarized PDF report or a JSON file digitally, which can be imported and shared with other researchers for refinement and re-evaluation in the future.

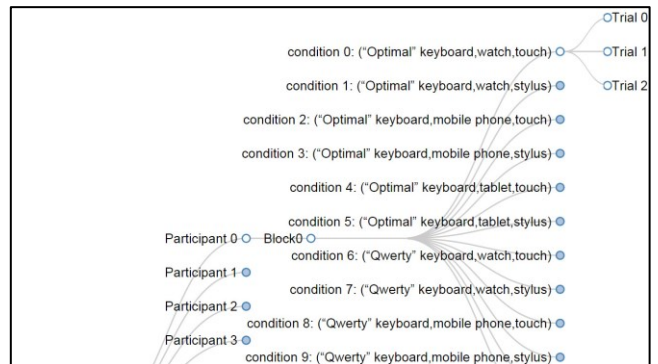


Figure 3. Simulation of the whole arrangement in the experiment (implemented using D3.js).

4. CONCLUSION

We proposed a 5-step approach to guide the design of controlled experiments and implemented it as a web-based open-source tool NexP (Next Experiment) that facilitates this designing process.

5. REFERENCES

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