PRE-PRINT – NOT PEER-REVIEWED

Opinion

Building, hosting, recruiting: A brief introduction to running behavioral experiments online

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Abstract: Researchers have ample reasons to take their experimental studies out of the lab and into the online wilderness. For some, it is out of necessity, due to an unforeseen laboratory closure or difficulties in recruiting on-site participants. Others want to benefit from the large and diverse online population. However, the transition from in-lab to online data acquisition is not trivial and might seem overwhelming at first. To facilitate this transition, we present an overview of actively maintained solutions for the critical components of successful online data acquisition: creating, hosting and recruiting. Our aim is to provide a brief introductory resource and discuss important considerations for researchers who are taking their first steps towards online experimentation.

Keywords: online experiments; behavioral sciences; online solutions

1. Introduction

In midst of the Covid-19 pandemic [1], many researchers are bound to rethink lab-based behavioral experiments [2]. There is an emerging need for online testing solutions for day-to-day research activities, thesis work and experimental practical courses alike. But even without a forced shutdown of physical labs, online experiments have gained popularity [3] in the last decade [4–8]. They offer great advantages in terms of participant diversity [9,10], time and resource efficiency [11]. This article is mainly aimed at researchers who have none or limited prior experience in conducting behavioral experiments within an online ecosystem. Our focus is on providing a conceptual overview of the critical components of online experimentation. We further summarize the most well-established tools for implementing these components and provide information about good starting points on the road to online studies. Finally, we offer some considerations and rules of thumb for succeeding with online acquisition, mainly focusing on feasibility and data quality.

2. How to run behavioral experiments online

The critical procedural pillars of *any* behavioral study are: (1) programming an experiment in the preferred software (e.g. E-prime, PsychoPy, PsychToolbox, etc.); (2) setting-up the testing machine (e.g. lab-computer, multi-unit testing facility, etc.) and (3) recruiting participants to conduct the study. The process of bringing experiments online requires the same pipeline but can be more demanding in terms of harmonizing these steps to ensure that each part of the pipeline is compatible with the other parts (Figure 1). For comprehensibility, we will outline each of these three steps in the next section. This will include a conceptual overview, but also specific examples of solutions (providers, software) which enable the corresponding step in the pipeline[1]. Some of the described solutions are quite modular and specialized (Table 1: B, C, D) in solving only individual steps of the

[1] Features and pricing are subject to change. For this reason, in this overview we discuss the main integrative possibilities, which we believe, will not change as quickly. For an up-2-date description of the detailed offerings, one should consult the respective websites.

process, whereas other providers offer a more holistic full-service ecosystem (Table 1: A). In section 2.4. we will discuss the considerations one should make when picking an ecosystem, but we will abstain for making strong recommendations and claims at this point. Notably, we limited this overview to software that appears to be under active development to ensure steady security updates (with updates in 2019).

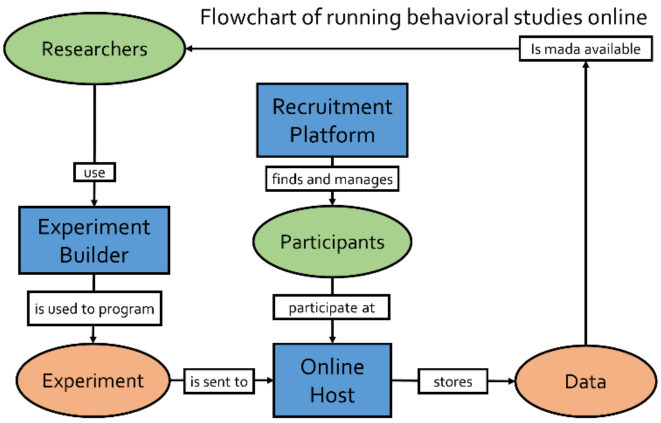

Figure 1. Schematic flow of conducting online experiments. First, experiments are created with an experiment builder. The compiled experimental files are then uploaded to an online host, which generates a link, making the study accessible online (potentially with the aid of a study management system). Participants are recruited through recruitment platforms and access the online experiments on the host. The data is saved on the hosting server.

2.1. Experiment builders

Equivalently to studies designed for in-lab testing, the first step in online experimentation is the programming of the experiment (Table 1B). In comparison to the hegemony of Python, C# and MATLAB based solutions for experimental programming of lab-based studies, Javascript (JS) is the language of choice for online experiments. Even though it is usually ranked as the most popular programming language in the world, JS has not been a hallmark in behavioral testing. Current solutions for online-experimental generation often provide a graphical user interface (GUI), enabling users to drag-and-drop modular components into an experimental sequence. As this rather simplistic, general solution is sometimes insufficiently flexible for more complex experimental designs, a good experimental environment should provide the possibility to extend these modular components with scripts and code-based solutions.

Arguably, the easiest transition from in-lab to online testing is granted by *PsychoPy Builder* [12–15] and *OpenSesame* [16,17]. Both environments are very popular for traditional testing and allow for a rather straight-forward restructuring towards their online counterparts (*PsychoJS* and *OSWeb*), if only their drag-and-drop modules were used to create experiments. All sections in which scripting was used (e.g. Python inserts) will need to be rewritten into Javascript by the experimenter. Fortunately, Python (especially its 'object-based' subset) and Javascript generally only differ in terms of syntax and not programming logic [18], so the rewriting is comparably easy. Additionally, PsychoPy auto-translates base-Python to JS (but not functions from specific libraries). There are plenty other experiment builders available: *Gorilla* [19], *Inquisit Web* [20], *LabVanced* [21] and *Testable* [22], from the full-service providers (see Table 1A) and *lab.js [23,24]*, *jsPsych* [25,26], *PsyToolkit* [27,28], *tatool web* [29] from the function-specific solutions (see Table 1B). Their advantages and shortcomings should be evaluated on a lab's basis depending on their individual needs. Generally, as all experiment builders (except for *Inquisit*) operate on a Javascript backend, they offer similar flexibility. They differ in available features (like example tasks or modules), but as all builders have online documentations, often with demonstration tasks available, researchers can quickly see whether they fit their specific needs. We see the most difficulties in transferring experiments online for *Psychtoolbox* [30] users, as *MATLAB®*'s proprietary backend offers no trivial translation to browser-based software.

Table 1. Simplified comparison of tools for online studies in respect to their features, advertised compatibilities (i.e. documentation on website), backends and costs.

	features and advertised compatibilities			platform cost per		backend
	Building	Hosting	Recruiting	monthly license	participant	
A. Integrated-service providers						
Gorilla.sc	✓	✓	MTurk, Prolific, SONA, *any*	-	~1 US$	visual
Inquisit Web	✓	✓	management	~200 US$	-	visual
Labvanced	✓	✓	✓	~387 US$	~1.5 US$	visual
testable	✓	✓	✓	n.a. [5]	n.a. [5]	visual
B. Experiment builders						
jsPsych (jsP)	✓	JATOS [1], Pavlovia	MTurk	free	free	JS
lab.js	✓	JATOS [1], Pavlovia, Open Lab, Qualtrics	MTurk	free	free	visual / JS
OpenSesame (OS)Web	✓	JATOS [1]	-	free	free	visual / JS
PsychoPy Builder (PPB)	✓	Pavlovia integrated [2]	-	free	free	visual / JS
PsyToolkit (PsyT)	✓	✓	SONA, MTurk	free	free	visual / JS
tatool Web	✓	✓	MTurk	free	free	visual / JS
C. Hosts and study management						
JATOS	lab.js, jsP, PsyT, OSWeb	(✓) [1]	MTurk, Prolific, [3]	free [1]	free	website
Pavlovia	lab.js, jsP, PPB	✓	SONA, Prolific, [3]	~145 US$	~0.30 US$	website
Open Lab	lab.js	✓	*any* [3]	~17 US$	free [6]	website
(inst.) webserver	lab,js, jsP, OSWeb, PPB	JATOS or none	*any* [3]	free	free	-
D. Recruitment services						
Amazon MTurk	*any*	-	✓	-	40%	website
ORSEE	*any*	-	(✓) [4]			
SONA	*any*	-	(✓) [4]	-	n.a.[7]	website
Prolific Academic	*any*	-	✓	-	33%	website
Qualtrics Panel	Qualtrics, any	-	✓	-	n.a.[7]	website

Note. JS: Javascript; [1] JATOS requires to be installed on your own (institutional) server machine; [2] PsychoPy Builder offers streamlined synchronization with Pavlovia; [3] Links can be shared to any platform or social media but extensive documentation is not available; [4] no active participant pool; [5] testable offers a mixed payment model; testable is also free for all departments in 2020 [31]; [6] up to 300 participants and one study; [7] only available upon request.

2.2. Hosting and study management

In lab-based studies, the final resting place of the finished experiment is the testing machine. For online studies, the experiment needs to be made available for online distribution by hosting it on a server (Table 1C). This is potentially the most confusing step in the pipeline of creating an online study. Some labs with a lot of experience in online experimentation host their studies on their own servers. This comes with the advantages of low maintenance costs, full control and flexibility. On the downside, it requires some expertise for setup and continued maintenance. The more feasible alternative is centralized hosting providers. Here, hosting and study management is a service, and as such, all providers require a fee. The general idea behind study management systems is to simplify the hosting and participant handling process, like user management, automated data storage or creation of unique participation links.

The whole range of features offered by different providers can be evaluated by visiting their websites. For example, one of the easier but not especially flexible hosting services is offered by *Open Lab* [32]. It takes all studies created with *lab.js* and tests some participants for free. Their unique selling point is arguably its integration with Open Science Framework (OSF) [33]. Participant data are directly uploaded to OSF, which could make it potentially interesting for multi-lab open science initiatives[2]. Another interesting example is *Pavlovia* [34]. You can upload HTML5/Javascript studies and there is documentation for importing studies created with *lab.js*, *jsPsych* and the *PsychoPy Builder (PsychoJS)*. It offers easy integration with recruitment tools and a GitLab platform [35] where experimenters can share their complete code. An example for more easily setting up one's own hosting platform is *Just Another Tool for Online Studies (JATOS) [36,37]*. *JATOS* similarly takes HTML5/Javascript studies and documents how to import studies created via *lab.js*, *jsPsych* and *Opensesame Web*. It offers a wide range of options and is a very comprehensive study management tool.

Finally, we want to highlight how important experiment-server compatibility is. In the examples above, we pointed out that a specific hosting service supports studies programmed by specific experimental builders. No host supports all experimental builds and no experimental build is compatible with all hosts. Thus, a decision should always be made on the level of the overall ecosystem and not on the individual components of the pipeline (building vs. hosting vs. recruiting).

2.3. Recruitment of participants

The dominant advantage of running experimental studies online lies in its efficiency. It is feasible to collect responses from hundreds of participants within hours. Thanks to the possibility of world-wide sampling, data collection can literally be completed over night. Once the experiment is created and accessible online (usually with a link), participants can be recruited. Due to higher participant numbers compared to most lab-based studies, handling this process manually is not advisable (for tools see Table 1D). ORSEE [38,39] and *Sona* [40] are participant pool management systems, which offer comprehensive automation tools. However, both require researchers to maintain their own (usually limited in size) participant pool. Additionally, only a limited number of participants can be recruited from the local University, via social media and (institutional) mailing lists. Maintaining an active pool of potential participants is the main advantage of *Amazon Mechanical Turk (MTurk)* [41–43], *Prolific Academic* [44,45] and *Qualtrics Panel* [46]. All three providers offer participant recruitment and payment handling services. As one essentially only needs a link to the study, they integrate well with the study management systems and experiment builders mentioned above (see Table 1 for details). While differences in their features are too narrow for the scope of this article, we will discuss some important points on data quality in section 3.

[2] It should be noted that there is neither a documentation, nor a privacy policy nor information about the responsible person or company publicly available.

2.4 How to choose an ecosystem?

Generally speaking, what researchers need for online experimentation is the same as what they need for lab-based studies (Figure 1): (1) a programmed experiment, (2) a server to host the study and (3) a recruiting platform which advertises to participants. As outlined in the previous sections, there are many solutions for each of these steps. Some solutions provide a single and holistic framework for all three aspects (Table 1: A), whereas other solutions are specifically tailored to one of the aspects and need to be integrated into an ecosystem by the experimenter. Here, the benefits and drawbacks mirror what we already know from software solutions in other domains. Full-service providers enable time savings by reducing compatibility issues, providing customer support, and reducing administrative load. On the flip side, they lack transparency, lack flexibility (minimal compatibility with other solutions), and are generally expensive. Non-profit and open-source solutions usually require more integration considerations and some of them lack direct customer support. Instead, they provide forums and community feedback, low or no costs, and more peer-reviewed benchmarks.

Ideally, the decision on which online ecosystem to use, should be made in accordance to the lab's capabilities and needs as well as criteria of quality (see section 3). General recommendations are hard to make, as labs' use cases are too diverse. Of note, switching from other software packages to a full-service provider has often the drawback that previously programmed experiments cannot be run anymore and even slight adaptations to the experiments (for example control studies that reviewer 2 asked for) are impossible without completely reprogramming the whole experiment. Therefore, when deciding how to transfer experiments to the online world, researchers should not only consider what the provider offers, but also how they can adapt their research to the new environment. From an open science perspective, it should also be considered, that experimental scripts cannot exported from all platforms.

The authors personally had good experiences with *OSWeb/JATOS* as well as *PsychoPy/Pavlovia* in combination with *Prolific* recruitment. Similarly, the authors would not recommend setting up experimental studies on self-maintained webservers without the aid of a study management system (e.g. *JATOS*) because of the need to account for everything that can go wrong, like handling data storage, assigning participant codes, assuring participants do not participate more than once, handling payment and so on.

3. Data quality concerns

The dominant concern with running experiments online is data quality. It is imaginable that stimulus presentation times are unreliable because of differing conditions in terms of internet speed or display settings throughout the experiment. However, almost all online solutions operate by downloading (pre-buffering) the entire experiment onto the participant's machine. Additionally, modern screen refresh rates are almost exclusively set to 60 Hz (de facto standard). Recently, two large studies investigated timing precision of several online and offline solutions and found good precision with only minor exceptions [47,48], most notably with audio playback. In addition to timing, there could be concerns that participants might be distracted more often when they sit at home and are not directly observed by the experimenter but several studies have shown that this is not necessarily the case [49,50] and data quality is comparable to lab-based studies [51–57]. However, experimenters should adjust their experiment to account for the sample diversity and participants' motivations [58].

4. Considerations for successful online studies

There are some aspects researchers should consider when starting out with running online studies or transferring lab-based experiments to online systems [59,60]. To a certain extent, creating successful online experiments is similar to app development: one needs to think of a coherent framework and constantly worry about what the users are doing with the 'product' and whether they are using it as intended - without many opportunities for direct feedback. Experimental instructions should be easy enough to be understood by a more diverse sample - not necessarily used to behavioral testing. Further, measures need to be taken to detect and discourage poor performance, that is 'fake' participation. Finally, online studies need to be shorter than classical lab-based studies.

Lab-based studies typically attract young WEIRD psychology students [61]. The samples drawn from online recruitment platforms are more representative [9,10]. Study participants have potentially never participated in a behavioral response time experiment. For this reason, experimenters need to be more thorough when creating experimental instructions and ascertain that they can stand on their own without verbal explanations (note: this is also a good recommendation for lab-based studies). It is crucial that the instructions are comprehensible by people of a wider age range representing many cultures and socio-economic backgrounds [10]. In the authors' experience, a pictorial step-by-step instruction leads to less misunderstandings or even dropouts compared to a single page of text. It is advisable that instructions are forced to stay on the screen for some time before continuation is allowed. In order to check whether participants have truly understood the instructions, a test run and online evaluation before beginning the main experiment is advised. Additionally, study management systems also incorporate some monitoring functions to check that participants stayed on track. For example, JATOS allows to monitor how often the browser tab running the experiment was minimized during the experiment.

The interaction between experimenter and participant is comparably indirect in online experiments. Therefore, participants might be less inclined to be attentive simply for the sake of helping the experimenter with their research. It should therefore be considered to state the relevance of the research explicitly. It was shown that *MTurk* participants perform better, when the task is presented as meaningful [62]. For many participants drawn from recruitment services, the dominant motivation for participation is monetary compensation. Typically, participants are paid a fixed amount after successful completion of the study - regardless of how long it takes them to complete it. This is why some participants try to complete the experiment as fast as possible without sticking to the instructions ('fake' participation). In order to ensure good data quality, the experimenters might need to adapt the experimental design to discourage such behavior. In the authors experience, an easy option for X-alternative-forced-choice tasks is to repeat the trial each time participants answered incorrectly. The authors also experienced less dropouts when a progress bar (comparable to surveys) was added. Gamification of the study might also yield better results [63].

Finally, online experimental studies should be short. Participants would possibly not sit 60 minutes in front of their screen and produce quality data. Since structured investigations are still missing, we asked 103 Germans through *appinio* [64] at which time they would abort an online experiment that offered minimum wage. Most respondents said 'after 15 minutes' (44%), followed by 'after 30 minutes' (35%), 'after 45 minutes' (10%) and 'after 60 minutes or never' (12%).

Keeping these considerations in mind, for a certain subset of investigations (certainly not all), carefully developed online studies have a huge potential. Many of the noise factors can be combated with a large sample size and intelligent preparatory work. Taking behavioral experiments online is facilitated by numerous steadily maintained tools ranging from simple libraries to complex ecosystems. Researchers need to wisely choose the software based on their own prior experience, the lab's resources and the requirements of the general area of study.

Author Contributions: Conceptualization, M.S. and D.D.; investigation, M.S. and D.D.; resources, M.S. and D.D..; writing—original draft preparation, M.S.; writing—review and editing, M.S., D.D. and W.M.; visualization, M.S.; supervision, W.M. All authors have read and agreed to the published version of the manuscript.

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