

EXPLORING THE **U**SABILITY **B**ARRIERS IN LIQUID **T**YPES

Research Guide

2023/2024

Table of Contents

RESEARCH GUIDE	1
Table of Contents	2
PROTOCOLS	3
Experienced Users - Current Users - Protocol	3
<i>Protocol Description</i>	3
<i>Questions for background and interview</i>	4
<i>Interview Script - Experienced Users - Current Users</i>	6
Experienced Users - Former Users - Protocol for the Interview and Retrospective	9
<i>Protocol Description</i>	9
<i>Questions for background and interview</i>	10
<i>Interview Script - Experienced Users - Former Users</i>	11
Newcomers - Protocol for the Usability Study and Interview	14
<i>Protocol Description</i>	14
<i>Questions for background and interview</i>	15
<i>Tutorial and Interview Script - Newcomers</i>	16

Protocols

This document presents the study protocols for the three activities we have defined, dependent on the user expertise level in LiquidHaskell.

Experienced Users - Current Users - Protocol

Protocol Description

- Before the session:

1. For recruiting participants, we will make a flyer available on the CMU campus, share the study over social media, send a message on LiquidHaskell Slack, and send emails to researchers who have published papers related to LiquidHaskell. The recruitment material will take the participants to a *Google form* where they can learn more about the study, select which category they want to participate in (experts, former users, or newcomers), fill out their contact information, and when they would like to schedule the study session.
2. The PI will email the participants to confirm or rearrange a meeting time for the study session either in person on the CMU campus or over Zoom.
3. The day before the session is scheduled, an email will be sent to the participants with the consent form and a reminder for the session on the following day.

- During the session:

1. Welcome the participant and explain the aim of the study;
 2. Ask the participant to read carefully the shared consent form (consent_form.pdf), and answer all the doubts that may arise;
 3. Request for the participant to sign the consent to participate in the study. Ask the participant not to provide any identifiable information during the session and turn off their personal computer notifications;
 4. According to the participant's authorization, start recording the session.
- [Interview – Background Information]**
5. The interviewer will ask about the participant's background on LiquidHaskell and Liquid Types. The prepared questions are presented in the next section.
 6. Before starting the observation part, the interviewer will explain what will happen in the observation part of the study since the participant will work on their current project.
 7. The interviewer will ask the participant to share their project with LiquidHaskell to explain what the project is about and what they are working on at the moment;
 8. The interviewer will tell the participant that they will change to the observation part of the study, where they can work on the project while using the thinking-aloud methodology;

9. During the next 30 minutes, the participant will share the project and share their thinking process aloud while they continue to develop it;

10. During this time, the interviewer will be taking notes and asking questions in the style of the master-apprentice method;

11. After the 30 minutes, the interviewer will finish the observation by communicating to the participant some conclusions of the observation to see if the participant concurs with the observations;

[Semi-structured Interview]

12. The interviewer will ask questions about the participants' previous experiences with LiquidHaskell and Liquid Types (the questions are presented in the next section of the document) while taking notes of the participant's answers and behaviors;

13. The participant will have time to make final comments and suggestions;

14. Finally, the interviewer will thank the participant for their time and ask if they would like to be informed of the results and consequent research on the topic. The interviewer will also ask if there is anything from the recording that the participant would like to cut.

Questions for background and interview

- Background

- What is your current work position?
- How long have you been working/using Liquid Types?
- How did you first learn about LiquidHaskell?

- Semi-structured Interview

- In which **cases** do you use Liquid Types in your projects, and in what **domains**?
 - Which target language?
 - **Why do you use** Liquid Types in those examples instead of other technologies? (e.g., for proofs, there are proof assistants; for verification there are testing techniques)
 - What sort of **problems** do you usually encounter while using them?
 - How do you usually **overcome** these problems?
 - What **improvements** would help you understand and fix the problems better?
- Use an example from the previous part or ask the participant to recall the last instance they had a problem while using Liquid Types.
- Can you explain what the problem was and how you fixed it?
 - What sort of **improvements** could have helped you understand and fix the problem better?
- Going back to when you **started** using Liquid Types, do you remember what kind of **difficulties** you found?

- Do you think those barriers are **still impeding people** from using Liquid Types?
- What do you **think we can do** to remove or reduce these barriers?
- What do you **envision as the future** of liquid types? In which scenarios do you think they will be used and by whom?

Interview Script - Experienced Users - Current Users

Introduction

- This study intends to understand how people learn how to use Liquid Types in Haskell and what barriers they face when learning and using them. We will observe you work on one of your own projects and ask you questions regarding your experience, challenges, and perspectives regarding Liquid Types in Haskell.
- At no point are we evaluating you. We value transparency as we want to understand the problems with liquid types so we can improve them, and understanding your struggles is an essential part of this process.
- We would like to record our session so that we can transcribe our interaction and process the information. Only the research team will have access to the recordings and transcripts. After the interview is transcribed, we will remove any identifying information. Are you okay with our session being recorded today?
- Since we will be recording the sessions, we ask you to not share any identifiable information and turn off your computer notifications during the session. Nonetheless, if there is any information that you would like us to remove from the recording at the end, just let us know and we will remove it.
- At the end of our session, you will be rewarded for your time with a \$10 Amazon Gift Card that will be sent to the email you used to register for the study. The gift card will be sent along with the cards for other participants, so it can take up to 2 weeks for you to receive it.
- Do you have any questions about the study?
- If you agree to participate, please read and sign the consent form shared with you through email. The form presents all this information. Feel free to read it, ask any clarification questions, and sign at the end.
- We will now turn the recording on.

Thank you very much for agreeing to participate. Let's delve into your experiences with LiquidHaskell and Liquid Types. I'd like to start by asking some background questions.

Background

- Can you tell us a bit more about yourself? What is your background and your current work position?
- When and how did you first hear about Liquid Types?
- How long have you been working/using Liquid Types?

Observation

Now, we will transition to the observation part of our study. In this phase, you will work on your current project involving LiquidHaskell. The goal is to observe how you apply Liquid Types in

real-time, which will provide us with insights into the practical use and challenges of the technology.

We'd like you to use the 'thinking aloud' methodology. This means as you work on your project, please share your thought process, decisions, and any challenges you encounter aloud. This approach will help us understand your workflow and the rationale behind your choices.

- Could you start by sharing more about the project you'll be working on today?

We're now going to begin the observation part of our study. Remember, there's no pressure to perform in a certain way; we're just interested in your natural workflow and how LiquidHaskell fits into it. Please feel free to start working on your project, and don't hesitate to verbalize your thought process as you go along.

**observe participant, take notes, and ask questions using the master-apprentice method*

Concluding Observation

**Share the key insights and conclusions you've gathered from the observation*

- Do these observations align with your experience?
- Is there anything you would like to add or clarify?

Semi-Structured Interview

- In which cases do you use Liquid Types in your projects, and in what domains? Which target language?
- Why do you use Liquid Types in those examples instead of other technologies? (e.g., for proofs, there are proof assistants; for verification, there are testing techniques)
- What sort of problems do you usually encounter while using them?
- How do you usually overcome these problems?
- What improvements would help you understand and fix the problems better?

**For the next two questions use an example from the previous part or ask the participant to recall the last instance they had a problem while using Liquid Types*

- Can you explain what the problem was and how you fixed it?
- What sort of improvements could have helped you understand and fix the problem better?
- Going back to when you started using Liquid Types, can you reconstruct what kind of difficulties you found?
- Do you think those barriers are still impeding people from using Liquid Types?
- What do you think we can do to remove or reduce these barriers?
- What do you envision as the future of liquid types?
- In which scenarios do you think they will be used and by whom?

Conclusion

- Are there any other questions that you think we should ask you?
- Any final comments you would like to tell us?

Thank you very much for your time and thank you for answering our questions.

Experienced Users - Former Users - Protocol for the Interview and Retrospective

Protocol Description

- Before the session:

1. For recruiting participants, we will make a flyer available on the CMU campus, share the study over social media, send a message on LiquidHaskell Slack, and send emails to researchers who have published papers related to LiquidHaskell. The recruitment material will take the participants to a *Google form* where they can learn more about the study, select which category they want to participate in (experts, former users, or newcomers), fill out their contact information, and when they would like to schedule the study session.

2. The PI will email the participants to confirm or rearrange a meeting time for the study session either in person on the CMU campus or over Zoom.

3. The day before the session is scheduled, an email will be sent to the participants with the consent form and a reminder for the session on the following day.

- During the synchronous session:

1. Welcome the participant and explain the aim of the study;

2. Ask the participant to read carefully the shared consent form (consent_form.pdf), and answer all the doubts that may arise;

3. Request for the participant to sign the consent to participate in the study. Ask the participant not to provide any identifiable information during the session and turn off their personal computer notifications;

4. According to the participant's authorization, start recording the session.

[Interview – Background Information + Semi-structured Interview]

5. The interviewer will ask questions about the participants' previous experiences with LiquidHaskell and Liquid Types (the questions are presented in the next section in the document) while taking notes of the participant's answers and behaviors;

6. If the participant has previous projects that they would like to share, we will move to a retrospective (step 7), if not we will move to the conclusion (step 11).

[Retrospective]

7. The interviewer will ask the participant to share one of their projects done with LiquidHaskell and to explain the project's intent.

8. The interviewer will ask the participant to remember the project's development process and tell them the main phases; some examples of questions to guide the interview can be found below (Questions for Retrospective).

9. During this time, the interviewer will take notes and ask relevant questions.

10. After recalling and answering questions about the project, the participant can share more projects (leading the interviewer back to 7b) or finish the retrospective and move into the interview part.

[Conclusion]

11. The participant will have time to make final comments and suggestions;

12. Finally, the interviewer will thank the participant for their time and ask if they would like to be informed of the results and consequent research on the topic. The interviewer will also ask if there is anything from the recording that the participant would like to cut.

Questions for background and interview

- Background

- What is your current **work** position?
- **When and how** did you first hear about Liquid Types?

- Semi-structured Interview

- What were your **first impressions** about the technique in terms of advantages and disadvantages?
- When you tried using them, what did you use them for? And do you think they were helpful?
- What type of **problems** did you encounter?

- What **improvements** could have helped get you started with using Liquid Types?
- Why **don't** you use Liquid Types in your projects now?
- What **changes** should be made so that you would use them in your projects?
- With what purposes do you envision yourself using Liquid Types in the future?

- Retrospective

- What is the domain of this project?
- What made you use LiquidHaskell in this project? Did you think about other options?
- Do you recall the process of using LiquidHaskell in this project? For example, did you usually write the specifications while writing the Haskell code, before writing the code, or after?
- In which parts of the code do you use LiquidHaskell?
- Do you iterate over the specifications you create?
- Can you recall any common issues that you usually run into?
- When an error occurs, how do you overcome it?
- Do you remember any specific parts of this project that were challenging for you? Why?
- Did you collaborate with others while doing this project? If yes, did the liquid types impact the collaboration?
- **How long** have you been working/using Liquid Types?

Interview Script - Experienced Users - Former Users

Introduction

- This study intends to understand how people learn how to use Liquid Types in Haskell and what barriers they face when learning and using them. We will ask you questions regarding your experience, challenges and perspectives regarding Liquid Types in Haskell, to gain a deeper understanding of their practical applications and barriers to adoption.
- Please feel free to share your honest and unfiltered feedback. We value transparency as we want to understand the problems with liquid types so we can improve them, and understanding your struggles is an essential part of this process. Additionally, LiquidHaskell was not developed by our team, it is simply the most mature implementation of Liquid types, and that is why we are targetting it for our study.
- We would like to record our session so that we can transcribe our interaction and process the information. Only the research team will have access to the recordings and transcripts. After the interview is transcribed we will remove any identifying information. Are you okay with our session being recorded today?
- Since we will be recording the sessions, we ask you to not share any identifiable information and turn off your computer notifications during the session. Nonetheless, if there is any information that you would like us to remove from the recording at the end, just let us know and we will remove it.
- At the end of our session, you will be rewarded for your time with a \$10 Amazon Gift Card, that will be sent to the email you used to register for the study. The gift card will be sent along with the cards for other participants, so it can take up to 2 weeks for you to receive it.
- Do you have any questions about the study?
- If you agree to participate, please read and sign the consent form shared with you through email. The form presents all this information. Feel free to read it, ask any clarification questions, and sign at the end.
- We will now turn the recording on.

Interview Questions

Thank you very much for agreeing to participate. Let's delve into your experiences with LiquidHaskell and Liquid Types. I'll be taking notes throughout our discussion to capture your thoughts and observations accurately. I'd like to start by asking some questions about your background and experience with Liquid Types.

Background

- Can you tell us a bit more about yourself? What is your background and your current work position?
- How long have you been working/using Liquid Types?
- How did you first learn about LiquidHaskell?

Questions

- What do you think were the advantages of using liquid types when you tried them?

Reasons

- What about the disadvantages? *Reasons*
- Does that connect to the reason why you don't use Liquid Types in your projects now?

Reasons

- When you tried using them, what did you use them for? *Domain*
- Can you recall the type of problems that you encounter? *Issues*
- What improvements could have helped you use Liquid Types? *Improvements*

Retrospective

Now, we'd like to explore one or more of your projects that utilized LiquidHaskell in detail. This part of our interview will help us understand the practical application of Liquid Types in real-world projects, including the motivations, development process, and challenges faced. Could you share with us one of your projects where you've used LiquidHaskell?

**for each project, cycle through the following questions:*

- What is the domain of this project? *Domain*
- What made you use LiquidHaskell in this project? Did you think about other options?

Reasons

- Do you recall the process of using LiquidHaskell in this project? For example, did you usually write the specifications while writing the Haskell code, before writing the code, or after? *Process*

- In which parts of the code do you use LiquidHaskell? *Process*
- Do you iterate over the specifications you create? *Process*
- Can you recall any common issues that you usually run into? *Issues*
- When an error occurs, how do you overcome it? *Issues*
- What about the error messages? Do you think they are helpful and easy to understand?

Issues

- Do you remember any specific parts of this project that were challenging for you? Why?

Issues

- Did you collaborate with others while doing this project? If yes, did the liquid types impact the collaboration? *Process*

Concluding Observation

**Share the key insights and conclusions you've gathered from the observation*

- Do these observations align with your experience? Is there anything you would like to add or clarify?
- Are there any changes that you think should be made to improve the usage of LiquidHaskell?
- Would these changes make you use Liquid Types again? Why or why not?
- With what purposes do you envision yourself using Liquid Types in the future?

Conclusion

- Are there any other questions that you think we should ask you?
- Any final comments you would like to tell us?

Thank you very much for your time and thank you for answering our questions.

Newcomers - Protocol for the Usability Study and Interview

Protocol Description

- Before the session:

1. For recruiting participants, we will make a flyer available on the CMU campus, share the study over social media, send a message on LiquidHaskell Slack, and send emails to researchers who have published papers related to LiquidHaskell. The recruitment material will take the participants to a *Google form* where they can learn more about the study, select which category they want to participate in (experts, former users, or newcomers), fill out their contact information, and when they would like to schedule the study session.
2. The PI will email the participants to confirm or rearrange a meeting time for the study session either in person on the CMU campus or over Zoom.
3. The day before the session is scheduled, an email will be sent to the participants with the consent form and a reminder for the session on the following day.

- During the synchronous session:

1. Welcome the participant and explain the aim of the study;
2. Ask the participant to read carefully the shared consent form (consent_form.pdf), and answer all the doubts that may arise;
3. Request for the participant to sign the consent to participate in the study. Ask the participant not to provide any identifiable information during the session and turn off their personal computer notifications;
4. According to the participant's authorization, start recording the session.

[Interview – Background Information]

5. The interviewer will ask questions about the participant's background. The prepared questions are presented in the next section.
6. Before starting the study, the interviewer will explain what will happen in the next part of the study;

[Tutorial]

7. The participant will be asked to follow an online tutorial on Liquid Haskell that includes questions that participants need to answer and exercises to complete. The tutorial is a reduced version of the full [LiquidHaskell tutorial](#).

8. At the end of the tutorial, the participant will be able to ask the interviewer questions if they need clarification about any previous examples.

9. The interviewer will explain that they will now move to the exercises where the participant must apply the information received in the tutorial and will try to complete them while using the thinking-aloud methodology. During the activities, the participants are free to move on if they feel like they cannot complete the exercise;

[Exercises]

10. The participant will be shown four exercises applying the elements learned in the tutorial. The first two exercises will be related to identifying and fixing the bugs against the

specification presented, and the last two exercises will ask the participant to add the liquid types to the Haskell code;

11. During this time, the interviewer will be taking notes but not interacting with the participant unless they ask protocol questions (e.g., can I move forward);

12. At the end of the exercises, the interviewer will tell the participant that this part of the session has finished, and now they will move on to answering some questions.

[Semi-structured Interview]

12. The interviewer will ask questions about the participants' experiences with LiquidHaskell and Liquid Types (the questions are presented in the next section of the document) while taking notes of the participant's answers and behaviors;

13. The participant will have time to make final comments and suggestions;

14. Finally, the interviewer will thank the participant for their time and ask if they would like to be informed of the results and consequent research on the topic. The interviewer will also ask if there is anything from the recording that the participant would like to cut.

Questions for background and interview

- *Background*

- What is your current **work** position?
- How long do you use **Haskell**, and for what purposes and domains?

- *Semi-structured interview*

- What was your first impression of LiquidHaskell and Liquid Types?
- What did you like the most about using Liquid Types?
- What did you dislike the most about using Liquid Types?
- Can you think of any improvements that would have helped you in this brief experience?
- Do you see yourself using Liquid Types in the future? If yes, in which cases?

Tutorial and Interview Script - Newcomers

Introduction

- This study intends to **understand** how people learn how to use this new technology of Liquid Types in Haskell and what **barriers** they face when learning and using them. Therefore, we will present you with a tutorial showcasing the main features of LiquidHaskell and will ask you questions regarding your experience while doing it.
- The tutorial exposes information about LiquidHaskell and its features. It also contains questions and exercises for you to complete. There are 3 tutorial parts, and then there will be a final exercise combining everything.
- At no point, we are evaluating you. We want to understand the problems with liquid types so we can improve them, and understanding your struggles is an essential part of it. Additionally, LiquidHaskell was not developed by our team, it is simply the most mature implementation of Liquid types, and that is why we are targetting it for our study.
- During the session, we will ask you to share your screen with us while completing the tutorial and the exercises, and we will record our session so that we can transcribe our interaction and process the information. Only the research team will have access to the recordings and transcripts. After the interview is transcribed we will remove any identifying information.
- Since we will be recording the sessions, we ask you to not share any identifiable information and turn off your computer notifications during the session. Nonetheless, if there is any information that you would like us to remove from the recording at the end, just let us know and we will remove it.
- After the end of our session, you will be rewarded for your time with a 10\$ Amazon Gift Card, that will be sent to the email you used to register in the study. The gift card will be sent along with the cards for other participants, so it can take up to 2 weeks for you to receive it.
- Do you have any questions about the study?
- If you agree to participate, please read and sign the consent form shared with you through email. The form presents all this information. Feel free to read it, ask any clarification questions, and sign at the end.

- We will now turn the recording on. *Send email with link of tutorial to the participant.*

Interview Questions

- Thank you very much for agreeing to participate.
Before we start the tutorial, let me ask you some background questions.

Background

- Can you tell me more about you - what is your academic and professional background?
 - In the registration, you mentioned you are familiar with Haskell. When did you first have contact with it?
 - How regularly do you use it currently?
 - In which kinds of projects do you usually use Haskell?
 - Are you familiar with any software verification or proof systems?
 - If yes, which ones are you familiar with?
- In this session, we will present you Liquid Types in Haskell, which help improve the reliability of software. You can access the tutorial from the link in the email we just sent. So please open the tutorial and share your screen.
- The tutorial has text, multiple choice questions, and coding exercises.
- If you have any questions, concerns, or doubts about the exercises, you are free to ask us. You are also free to move to the next exercises without finishing the previous ones, but you cannot go back.
Again, we are not evaluating you but the system that you will be using, so feel free to raise concerns.
- You can now start the tutorial.

Throughout the Tutorial

If a participant seems stuck in a part or exercise - e.g., has made 2 attempts without getting the correct answer, is looking confused, are scrolling through the page. Ask some of the following questions:

- What is going through your mind?
- Would you like any clarifications?
- Are you struggling with anything specific?

For the coding exercises, take notes of:

-the process taken to write the code (e.g., do they scroll to find something, jump straight ahead, etc.)

- was it correct at first*
- what were the initial errors/problems*
- did they check the answers?*
- did they run the code and were there any errors showing, if yes, did they read them?*

Part 1 - Tutorial Introduction

No interview questions.

Part 2 - Refinement Types

Questions.

- What do you think so far about adding the specifications?
- Have you heard about dependent types before? Do they make sense to you?
- What did you think about the error messages above? Were you able to read and understand them?
- Would you like any clarifications?

Part 3 - Refined Datatypes

- Did anything stand out to you in this section?
- Were there any concepts that made more or less sense?

- These were the main tutorial tasks; now, we will move to an exercise to put all of these concepts into practice.

Part 4 - Exercise

At the start:

- This exercise focuses on this special implementation of queues, and we will make their implementation more reliable with LiquidHaskell.

- During the exercises, we will ask you to change to a think-aloud methodology, which means that we would like you to say aloud what you are thinking about when completing the exercise. There are indications in the tutorial to switch to this mode.

At the end:

- For this last exercise, can you reconstruct your thought process?
- In this implementation of lazy queues, what was the most challenging exercise?
- Why?
- What were the most difficult concepts to understand?
- If you could, would try applying LiquidHaskell to another example?

Final Interview Questions

- Now we finished the tutorial, so I would like to ask you some final questions about this experience.

- What was your first impression of LiquidHaskell?
- Did that view evolve throughout this short tutorial?
- What do you think would be the main use of refinement types in other projects?
- Was the added effort for adding the specification worth it for this goal?
- What did you like the most about using Liquid Types, if anything? - What about things you disliked if any?
- Can you think of any improvements that would have helped you in this brief experience?
- Do you see yourself using Liquid Types in the future? If yes, in which cases?
- Great, are there any other questions that you think we should ask you?
- Any final comments you would like to tell us?

Conclusions

- Thank you very much for your time and to answer your questions. We hope this was a chance to learn something new.