Behavior study of the cellar spider, *Pholcus phalangioides*, using Image recognition and data collection instrumentation

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Background and Significance

Long-bodied cellar spiders (*Pholcus phalangioides*), are a tropical species that has found a niche in human dwellings such as homes, sheds, barns, or commercial buildings, often in dark and damp places like the corners of windows, ceilings, basements, etc. Studies have shown that they tend to construct loose, irregular webs in areas with higher relative humidity and moisture. This species of spider is considered beneficial in parts of the world because it preys on other spiders, including species considered dangerous through effective defensive and predatory behaviors. Commonly found in human buildings, *P. phalangioides* primarily attack, kill and eradicate native spider species but are known to be harmless to humans. Moreover, it's been reported that these spider webs have a potential for medicinal use.

Cellar spiders, unlike other spider species, layer new webs on top of the old ones rather than reconstructing or reusing their old webs which leads to an excessive web buildup over time (Pestworld.org, 2021). These space webs are used for prey-catching purposes: a prey (spiders and insects) that trips over the edge of the web without successfully entering the web will be engulfed in a layer of silk thrown by *P. phalangioides.* They, however, avoid attacking prey away from the web (Jackson et al., 1987).

Building webs is not an easy task and requires a lot of time and effort from the spiders which could rather be spent eating and/or mating. In addition to their wrapping behavior, *P. phalangioides* also invade webs of other spiders and feed on the occupants by performing aggressive specialized vibratory behaviors that trick the prey into thinking they've caught an insect or spider onto their web (Jackson et al., 1987). It is important to note, however, that there's experimental evidence of their vision being of little to no importance in the process.

P. phalangioides are sexually dimorphic where females are slightly larger than males. They also boast eight very long thin legs which are covered in thin, grey bristles. These hairy legs make up for their lack of vision by acting as tools for picking up chemical cues from their environment. There are species of spiders such as *Pholcus manueli* that can tell the size of a web builder by smelling the chemicals left on its web silk and can be used as a predatory advantage when trying to size up to a bigger spider (Swift 2021). *P. phalangioides*' long legs also help them maintain a safe distance from the prey to avoid being bitten in retaliation. They're also capable of clinging onto the web with only 2 of their legs while the rest of the body leans out the web and shoots silk at the prey (Jackson et al., 1987).

In cases where *P. phalangioides* are being preyed upon, they perform their primary defense strategy of whirling. Whirling is when a spider gyrates/swings its body around in a circle repeatedly while its legs stay fixed on the web. The duration of the whirling varies based on the kind of predator or the situation. Long duration whirling is most commonly done in response to more threatening spider presence such as jumping spiders. The rapid gyration disturbs the vision of the Salticids (jumping spiders) so that they can no longer rely on their vision to pinpoint the location of *P. phalangioides* (Wikipedia).

Long duration whirling shown by the pholcid spider *Pholcus phalangioides* has been studied. Specifically, they are elicited by the Salticid spiders and hardly ever to predatory spiders from other families. It is also known that short duration whirling is demonstrated to favor survival of pholcidae in the presence of all sorts of predatory spiders (Heuts et al., 2001). Jumping spiders of the salticidae family have well developed eyes which mediate their highly stereotyped predatory and communicative behaviors.

There's behavioral evidence of how well developed vision in jumping spiders is. It was collected by allowing these spiders to view images of videotapes prey and spiders on Sony Watchman micro-television units. The evidence suggested that jumping spiders do indeed interpret video images as real given their acute eyesight since they didn't discriminate between live prey and its simultaneously presented video image. They also behaved appropriately when presented with televised images of prey insects, conspecifics and heterospecific jumping spider species (Clark et al., 1990).

No evidence of such study being conducted on *P. phalangioides* or cellar spiders has been found yet. In fact, there's very little interesting behavioral research that has been done on *P. phalangiodes.* Any studies that have been conducted involve data collection through human observation and video footage. The main goal of my thesis is to study the behavior of cellar spiders or *P. phalangioides* through the means of a data collection device involving the use of stimuli-inducing software/hardware to keep humans from invading their spaces and make the process more automated. This device will keep track of and record the Pholcid behavior in different experimental settings.

Objectives

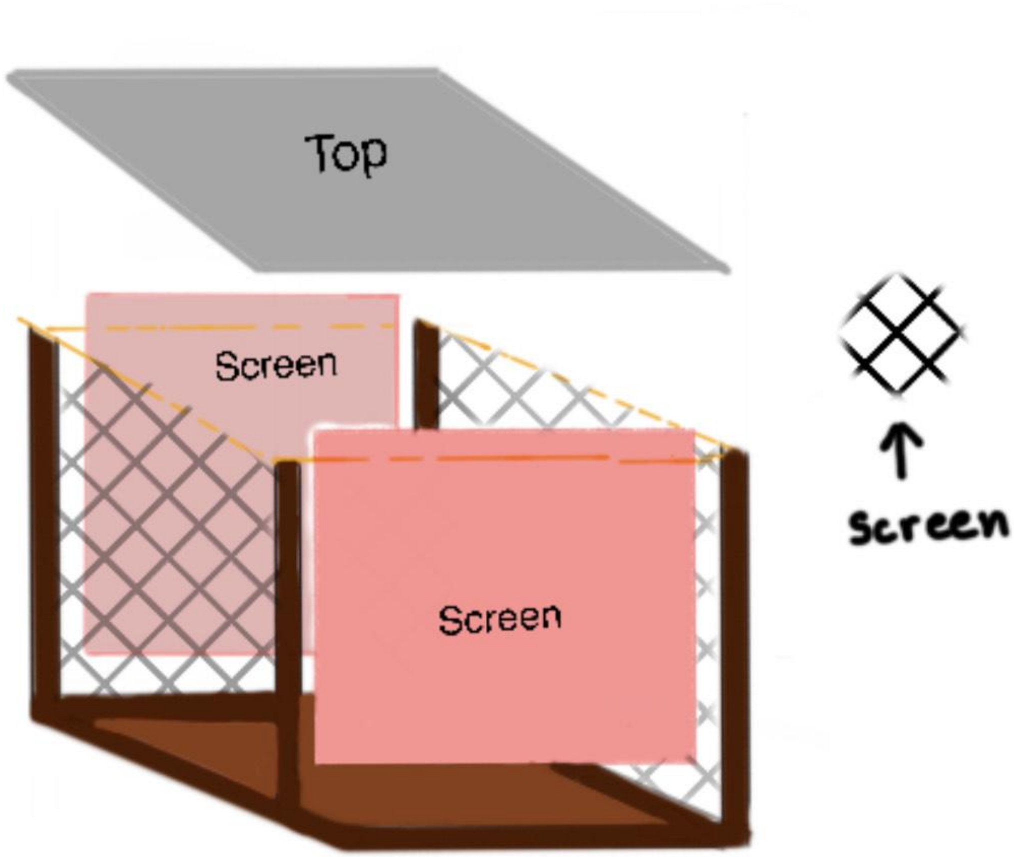
I will construct an instrument to present stimuli to long-bodied cellar spiders or *P. phalangioides* and record video of their behavioral responses. Specifically, evidence of jumping spiders interpreting video images as reality has been gathered. I aim to carry out experiments through the device and environment I will build to study how cellar spiders would react to video footage. The hypothesis is that there will not be any significant reaction given the fact that *P. phalangioides* have a bad vision. If the hypothesis is tested correctly, the next step is to see if they react to other kinds of stimuli given their lack of vision senses.

Literature studies have shown that *P. phalangioides* make up for their poor eyesight by relying on a combination of other senses — vibrations, touch and taste. Another goal of my thesis is to gather data to demonstrate the prior. Since touch and taste are other senses cellar spiders rely on, I propose to test their behavior in the presence of live and fake 3D printed jumping spiders to record the whirling behavior. The final goal of this study is to test if the environment (light vs. dark) affects how active the spiders are or to what extent they showcase the described behaviors. I hypothesize that it shouldn't matter given poor eyesight and their heavy reliance on chemical cues.

A personal objective is to gain more expertise working with technical instruments and software while gaining hands-on knowledge on applying those skills to aid in answering a research question. Data collection is an important aspect of many real world problems and learning how to effectively collect and analyze that data is quite crucial for the success of the projects and an immensely helpful skill to have.

Materials and Methodology

The first step to accomplishing my goals is to create a multipurpose environment for the spider. I plan on carrying it out by building a wood box with slots to insert screens as the four walls. This will aid in switching between light and dark surroundings for the spider and for switching from glass to LCD screens for video presentation. It will look something like the figure below:



The dimensions of the box will depend on the screen sizes. Next, I will install 2 raspberry pi 4 IR-CUT night vision cameras in the box to capture images and video recordings of the spider in the box to observe the behavior. These cameras will be connected to a raspberry pi and will communicate and collect the data through arduino. My goal is to program a software such that the cameras function only when they receive a signal such as the movement of a spider. This could be done through some image recognition and machine learning techniques which I will have to investigate further given the size of the spider and the ability of the cameras to capture the spider. The data collected can then be used to graph the activity patterns of the spider. The video/image feed will demonstrate the reaction of the spider to various stimuli.

The first goal of this project is to present *P. phalangiodes* with video footage and record its ability to distinguish the video from reality similar to the study performed on jumping spiders. This will be achieved through the installation of LCD screens for one of the walls of the box as the image suggests.

To study predator-prey behavior, especially salticid specific anti-predatory behavior, I will first introduce a live jumping spider into the box and capture those behaviors, then compare the results with the situation where a 3D printed jumping spider is put onto the spider web. I will also be putting in 2 piezoelectric sensors: (1) Piezo Buzzer that will be set off when sent a signal which will then cause the webs to vibrate, hopefully tricking *P. phalangiodes* into thinking it's caught a prey, (2) Vibration sensor that will go off when it senses the whirling behavior as a defense mechanism against a predator. The PIR sensor is a motion sensor that will capture any movement by the spiders.

The final aspect of the project is to see whether the surroundings cause the spiders to act differently or affect its activity. All of the above will be carried out in both dark and light environments by switching the glass walls with a darker screen. The goal is to build a prototype instrument by the end of this semester and calibrate it accordingly leading up to the creation of the final instrument in Spring '22. There will be two final versions of the instruments deployed by the end of next semester with one of the two serving as a backup in case of issues/breakage of the first version.

Advising and Technical Trainings

I have been receiving basic technical training regarding the use of arduino, raspberry pi along with the introduction of python in programming these devices to do certain tasks in class by Dr. Steven D. Brewer. These in-class training along with weekly consultations with him have been keeping me on track to move in the right direction with my thesis. The research will be carried out in part at my own apartment and also at the All-campus Makerspace that has all the required resources, guidance and tools to put together my data collection instrument.

Budget

Item	**Quantity**	**Unit price ($)**	**Total ($)**
LCD Screen	4	49.98	199.92
Raspberry Pi 4 Model B	3	55.0	165
Power Supply Adapters for RasPi	3	7.95	23.85
Aluminum Heatsink with RasPi case (To keep the RasPi cool in case of high power usage and a case to keep it secure)	3	24.95	74.85
Spool of Filament (3D printing)	1	23.97	23.97

Jumping Spider (Baby)	1	29.99	29.99
Cellar spiders	Pack of 12	43.00	43.00
SD cards 64 GB	12	10.99	131.88
Raspberry pi 4 IR-CUT night vision cameras	6	22.99	137.94
Piezoelectric vibration sensor (senses vibrations)	3	15	45
Piezo Buzzers (creates vibrations)	6-pack	8.98	8.98
PIR sensors (movement tracking; motion sensor)	6	9.95	59.7
Arduino Uno R3	2	23.00	46.00
TOTAL			**990.08**

References

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