**Section 1:**

The overall purpose of this study is to measure the respiratory rate and heart rate using light. Respiratory rate and heart rate monitoring have long been used in research and clinical applications as a measure of emotional stress[1,2], fatigue[3] , responses to exercise [4], and as an early warning sign of clinical decline in aging populations [5]. Remote continuous monitoring of these vital signs has been conducted in both clinical and nonclinical environments [6,7,8], where the application of electrocardiography (EEG) probes, full-body mechanical strain gauges. acoustic sensors, capnography, or electronic transducer probes [9,10] have traditionally been used. Such approaches have faced barriers to widespread adoption due to either being invasive, prone to interference from the ambient surroundings and motion, uncomfortable means of application, or difficulty in utilizing in neonatal and elderly populations.

Light based remote heart rate and respiratory rate measurement devices have shown success in challenging environments such as in neonatal monitoring [15,16,17] and in motion based tasks [18,19]. However, optical-based approaches suffer from low signal to noise ratios (SNR) in environments with low levels of ambient light such as at night [11,12]. Alternative methods such as through illumination with near infrared (NIR) sources in structure sensors, as well as through thermal cameras have shown feasibility in robustly measuring cardiac rate and respiratory rates in these low light environments [13,14].

The proposed illumination sources and detectors will be mounted on robotic system that will allow for the source and detector to be positioned optimally as to maximize data quality. We propose the usage of a FLIR Lepton 3.5 thermal camera mounted with a PureThermal breakout board, a standard RGB webcam, as well as a FLIR Blackfly camera with NIR sensitivity (BFS-U3-28S5M-C). For illumination in dark environments, we are proposing to use an Occipital Structure Sensor (ST01). This sensor illuminates between 815-850 nm using a class 1 laser acting as a diverging beam. The device is expected to illuminate the entire face and chest region of a subject from variable distances between 0.5m and 3m. Peak power was measured at 830 nm to be 54 mW/cm2 immediately upon exiting the surface of illumination. At 0.5m from the source, peak 830 nm power was measured to be 0.47 mW/cm2 with even lower measurements as the distance increases due to power dissipation. This range of observations is well within ANSI standards. Depending on the environmental condition tested, we plan on using all or some of these subsystems to obtain continuous respiratory rate and heart rate measurements through computer vision and signal processing approaches applied to facial regions.

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**Section 2:**

1. To acquire respiratory rate and heart rate measurements over variable environmental conditions including but not limited to:
   1. Variable distances of subject to camera between 0.5 m and 3 m
   2. Variable levels of ambient lighting
2. Use collected dataset to establish confidence criterion for each subsystem (color system, thermal imaging system, NIR system)

**Section 3:**

The goal of the study is to assess our optics-based approaches to measuring respiratory rate and heart rate in a variety of ambient conditions. The results of this study should help establish confidence criterion for each of our subsystems. Specifically, we will evaluate under which conditions we are able to acquire respiratory rate and heart rate measurements comparable to that of wearable systems such as pulse oximeters or transducer belts. The collected data can act as guide for future algorithm development or successive hardware iterations that allow for higher quality data acquisition during more complex testing scenarios such as during exercise and subject movement. All our proposed methods are noninvasive and safe.

**Section 4:**

* Dr. Qianqian Fang, Associate Professor, BIOE Department of NEU, is responsible for the optical remote vital sensing component of the project, as well as training and supervising all researchers handling this platform.
* Dr. Miguel Mireles, Postdoctoral Research Associate, BIOE Department at NEU, is the project leader who will coordinate the team’s timely delivery of all expected project outcomes.
* Rahul Ragunathan, PhD Student, BIOE Department at NEU, who will be the primary point of contact for maintaining and developing the sensor suite.

**Section 5: Study Procedures**

Patients will be required to wear a commercially available pulse oximeter as well as a commercially available respiratory rate wearable measurement device such as a mechanical transducer belt or acoustic sensor suite that will stream data to a laptop simultaneously with the noncontact system as a control. A brief controlled breathing task using a metronome as guidance will be conducted at 12 and 20 breaths per minute to ensure proper placement of the wearable respiratory device prior to starting data acquisition (~1-2 minutes). The controlled breathing task will be modified to a different breaths per minute rate if the subject suffers from any discomfort or pain. In addition, a baseline resting heart rate measurement will be acquired each time the subject shifts position from lying down to sitting or vice versa to allow the signal to stabilize (~ 1 minute).

Subjects will be required to remain as still as possible for the duration of each measurement. Each measurement per tested condition will be fixed at 90 seconds in duration. Patients will either be seated idly in a chair or be lying down in a bed such that the entirety of the face and upper chest will be visible to the NIR source and each of the cameras. Lighting control present in the room will allow for ambient lighting to be set to either “off” (similar to at night), “medium” (similar to normal room lighting), “high” (well- lit room in close proximity to a window). The distance from the subject to the camera will varied between 0.5m, 1m, 1.5m, 2m, 2.5m, and 3m by some combination of moving the noncontact sensor suite with the robot or repositioning the subject. Regardless of the lighting condition used, the subject will be repositioned such that the subject face and chest regions are uniformly illuminated to the best ability of the operator. In addition, subjects will be repositioned to ensure that no high/low temperature artifacts such as AC vents/ heaters are present in the shot as to not affect thermal camera measurements. The thermal camera, NIR camera, structure sensor illumination, and RGB webcam camera will be used to acquire data simultaneously to minimize patient discomfort and total measurement time. Each of the systems poses minimal risk to the subject while ensuring minimal interference between subsystem data recordings. **Table 1** summarizes our proposed study conditions. Measurement time should be roughly 54 minutes excluding time taken for calibration. Total time requested from the patient for the study should be no more than ~ 2 hours to allow adequate time for the subject to rest and to allow for sufficient time to calibrate the wearable sensors prior to data acquisition.

Table 1: Proposed Study Design

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Total Video length (s)** | **# Measurement Conditions** | **# Lighting Conditions** | **# Poses** | **Total time (minutes)** |
| 90 | 6 | 3 | 2 | 54 |
|  |  | | | |
| **Measurement Distances(m)** | **Lighting Conditions** | **Pose conditions** |  |
| 0.5 | Off | Lying Down |
| 1 | Medium | Sitting in chair |
| 1.5 | High |  |
| 2 |  | |
| 2.5 |
| 3 |

**Section 6:**

 The experiment could be conducted by any person on the team, and will take place at **INSERT RICHARD HALLS LOCATIONS**

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Section 7: Safety**

Risks of Infrared Radiation (IR) Light**:**

Patient positioning and prior measurements indicate that patient exposure to NIR radiation is well within ANSI safety guidelines. No safety eyewear is necessary by either the operator or the subject.

All other measurements are passive in nature and pose no risk to the subject.

Patient Privacy and Identity protection

To protect privacy, all study forms will bear a study ID identifier and only the consent and payment forms will contain the subject’s identifiable information. The subjects enrolled and their IDs will be kept in a password protected database on the principal investigator’s computer along with recorded raw video files and any processed data (processed data contains no identifiable information).

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**Section 8:**

Participants can take breaks between trials as much as needed. They may also terminate the session at any time. The equipment is designed to electrically isolate the participant from any power source and no risk of electrical shock is anticipated.