

# ReCUR

Red Cedar Undergraduate Research

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# About ReCUR

ReCUR is a publication of the Michigan State University Honors College that highlights the diversity and quality of our students' research and creative endeavors. Each issue of ReCUR accepts submissions from Honors College students and from participants in the University Undergraduate Research & Arts Forum (UURAF). In addition to providing students an outlet for publication of their work, ReCUR offers students an opportunity to become familiar with the editorial process as members of the Editorial Staff or Student Editorial Board.

## About Citation Formats

As ReCUR is an interdisciplinary journal, we respect the citation formats of the various fields of our authors. Thus, readers will notice in-text and reference list differences depending on the style guide the author has used. General stylistic issues are edited per the *Chicago Manual of Style*.

## Call for Submissions

### HONORS COLLEGE STUDENTS AND UURAF PARTICIPANTS:

ReCUR is now accepting submissions for the next issue from Honors College students and UURAF participants. Please visit our website at [recur.msu.edu](http://recur.msu.edu) for more information.

# About the Cover

The Volume 7 cover of ReCUR is "The Spider's Jewels," a photograph of a dew-laden spider's web by Tabitha Rose, a fourth-year food science student in the Honors College. The inspiration for this piece came from the light reflecting off dew droplets, reminiscent of a necklace of sparkling diamonds on a thin silver chain. This image captures the beauty and riches that are all around us in nature if only we look for them. Rose received an honorable mention for the photograph in the Honors College inaugural art contest in January 2017.

Honors College student drawings, painting, graphic designs and photography were reviewed by a committee of faculty, staff and students; the winning artwork are on display in Eustace-Cole Hall. First place was awarded to Rachel Emerick, a second-year mechanical engineering student in the Honors College, for her piece "Nostalgia."

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**The Spider's Jewels**  
Tabitha Rose



**Nostalgia**  
Rachel Emerick

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# Perches in Orchards Attract Two Beneficial Bird Species

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## Abstract

Cherry production is a large and economically important industry in Michigan. However, fruit growers incur a significant economic loss due to bird damage every year. Biological control by birds of prey may be a way to reduce crop damage and lessen the impact on the environment with minimal cost and effort. In this study, we attempted to determine whether the use of man-made perches would attract the Cooper's Hawk (*Accipiter cooperii*) to cherry orchards to consume damage-causing birds in northwestern Michigan. Over the study period, we broadcasted Cooper's Hawk calls in cherry orchards to detect raptors in the area. We also recorded video of the perches to determine if the Cooper's Hawk or other bird species were using the perches. We did not detect any Cooper's Hawks on the videos or during broadcasts, however, other species beneficial to fruit growers, such as the American Kestrel (*Falco sparverius*) used the perches during filming.

## Introduction

Fruit production in the United States generates \$15 billion per year (Anderson et al., 2013). In Michigan, sweet and tart cherry production was valued at approximately \$72 million (Michigan Department of Agriculture, 2017). Unfortunately, bird damage to these crops is costly; economic loss of sweet and tart cherries has been reported at more than \$4.3 million in Michigan alone (Anderson et al., 2013). The authors also reported that bird damage caused 13.3% and 4.8% yield losses in sweet and tart cherries, respectively.

To reduce bird damage, chemical repellants and lethal shooting (to kill some birds and scare others) are used with varying degrees of efficacy (Anderson et al., 2013). However, two current areas of environmental concern are the large amount of chemicals used in agriculture (Herrnstadt et al., 2016) and the loss of biodiversity (Straub et al., 2008). Conserva-

tion biological control, or manipulating habitats to increase predator presence (or other enemies of a pest) in agriculture habitats, is a possible solution to pest problems that can reduce the use of chemicals, increase biodiversity (Straub et al., 2008), and potentially increase local populations of species that are helpful to farmers. An example of this occurred in New Zealand, where introducing the New Zealand falcon (*Falco novaeseelandiae*) to vineyards significantly reduced bird damage to grapes (Kross et al., 2012).

A bird species that could potentially be used to mitigate damage in the United States is the Cooper's Hawk, which generally preys on small- and medium-sized birds. American Robin (*Turdus migratorius*), European Starling (*Sturnus vulgaris*), and House Sparrow (*Passer domesticus*) make up the majority of their diet (Cava et al., 2012). According to Anderson et al. (2013), fruit growers ranked the American Robin and European Starling first and second, respectively, in causing damage to tart and sweet cherries. Additionally, Lindell et al. (2012) found that robins were the most commonly detected bird species in cherry orchards, although, overall they did not consume as many cherries as the Cedar Waxwing (*Bombycilla cedrorum*). Based on their diet, the Cooper's Hawk has the potential to be predators that reduce bird damage. However, Cooper's Hawk have been found to prefer low-density residential areas to agricultural areas (Boggie & Mannan, 2014). Cooper's Hawks also tend to stay close to their nesting area, especially during the breeding season (Boggie & Mannan, 2014). Therefore, in order for the Cooper's Hawk to reduce bird damage in fruit crops, there must be a breeding population in the area.

This study attempted to determine if the Cooper's Hawk nest in northwestern lower Michigan, and if there is a way to make agricultural areas more attractive hunting areas for them. To determine presence, playback calls were used to find if there were breeding populations of the Cooper's Hawk near the study sites: six tart and sweet cherry orchards. Elevated

**TABLE 1.** Summary of hours of recording time at perches and information about control and treatment orchards used.

Orchard	County	Crop	Minimum Hours of Recording Time
1	Leelanau	Tart Cherries	170.9
2	Leelanau	Sweet Cherries	128.5
3	Leelanau	Sweet Cherries	222.6
4	Leelanau	Sweet Cherries	151.0
5	Benzie	Tart Cherries/Sweet Cherries/Apricots	101.5
6	Leelanau	Tart Cherries	176.5
7	Leelanau	Sweet Cherries	N/A (control)
8	Leelanau	Sweet Cherries	N/A (control)
9	Leelanau	Sweet Cherries	N/A (control)

perches have been known to attract predators as they facilitate prey detection (Andersson et al., 2009; Reinert, 1984). Cooper’s Hawk have been known to use dead trees as perches for hunting (Reinert, 1984); however, it is not practical to erect dead trees within orchards. Therefore, to make the orchards more attractive areas for hunting, man-made perches were installed in the study sites and monitored throughout the study period.

## Methods

This study was conducted during the summer of 2015, from late May to mid-August in northwestern Michigan in Leelanau and Benzie counties. To assess the presence and use of man-made perches by the Cooper’s Hawk in and surrounding mature cherry orchards, six treatment and three control orchards were chosen after a cooperator request was circulated to local fruit growers, and responses from growers interested in the study were obtained. The sites were all within 52 km of each other, and were all at least partially sweet or tart cherry orchards (Table 1). Study orchards all had a tree line or wooded area of trees at least five meters tall along at least one edge of the orchard. In the six treatment sites, two 18-foot tall perches were placed within and on the edge of the orchard. One perch was placed in the tree line, while one perch was put in the orchard with the cherry trees. The perches were made of two, 10-foot tall galvanized pipes, the bottom a one inch diameter pipe and the top a ¾ inch diameter pipe screwed together with a reducing coupler. At the top of the ¾ inch pipe, a flange was screwed on to attach the 2-foot long wooden perch. The pole

was placed in a hole in the ground with a depth of two feet. To stabilize the pole, the pipe was placed over a four-foot long piece of rebar.

Broadcasting vocalizations of the Cooper’s Hawk increases the probability that an observer will detect a Cooper’s Hawk in the surrounding area, making playback of taped calls a useful tool in surveying for these hawks (Rosenfield et al., 1988; Rosenfield et al., 1985). At all of the orchards, broadcast surveys were conducted by the first author every other week in the morning between 8:30 and 11:00, beginning on May 26th, 2015. These surveys consisted of six-minute pre-broadcast, broadcast, and post-broadcast periods (Mosher & Fuller, 1996; Mosher et al., 1990), and were conducted seven times at the treatment sites and six times at the control sites. During the broadcast period, a 15-second Cooper’s Hawk vocalization was played at the top of each minute. During the surveys, the observer stood at the edge of the orchard near the tree line, between the two perches set up in the orchard. The broadcast point was between four and ten meters from the tree line, and the perches were all 30 to 60 meters apart, except for Orchard 1, where the distance was 109 meters apart due to site constraints. Between call broadcasts, the speaker was rotated 180° in order to face one perch at each broadcast. The observer faced the tree line during the survey. During these surveys, the observer recorded any visual or auditory detection of raptors and the time at which the detection occurred.

A waterproof security camera was placed at the top edge of the perch, and was used to record time and duration of perch use for any bird species landing on

the perches beginning on June 5th, 2015 (Table 1). To record footage of the perch, battery-powered recording setups were used, which contained a DVR and a power inverter in plastic, weatherproof tubs. To give each orchard approximately equal recording time, these recording setups were placed at two orchards at a time for typically three to five days before being rotated to the other orchards periodically throughout the season. The minimum recording hours are shown in Table 1.

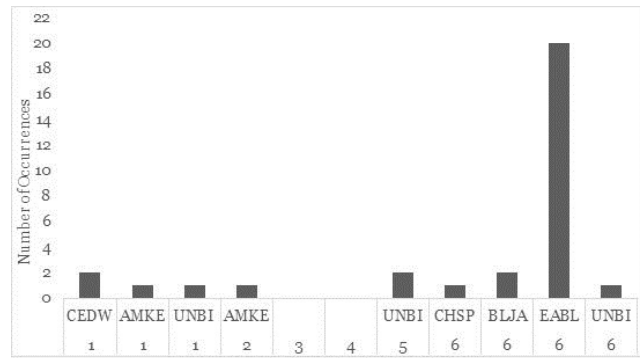
## Results

During the study period, there was no auditory or video detection of the Cooper's Hawk. There were five auditory detections of potential raptors during the surveys; however, there was no visual detection and there was no certainty about the identity of the species from vocalizations. One detection was an unidentified owl, another an unidentified raptor thought to be an American Kestrel, and three calls were recorded as unidentified raptors, but were likely the Northern Flicker (*Colaptes auratus*), which sounds similar to raptors.

While there were no occurrences of the Cooper's Hawk on the video records of the perches, there were other species that used the perches, including the American Kestrel. The species seen at the perches are shown in Figure 1, along with the orchard where they were seen and the number of times they were seen using the perches. There were no species seen at orchards 3 and 4; the Eastern Bluebird (*Sialia sialis*) were only seen at orchard 6 and were recorded on the perches within that orchard many times. Additionally, other species were seen on the perches, including the Cedar Waxwing (*Bombycilla cedrorum*), Chipping Sparrow (*Spizella passerina*), and Blue Jay (*Cyanocitta cristata*).

## Discussion

This study investigated whether there were breeding Cooper's Hawk populations in northwestern Michigan near orchards, and if these orchards could be made into viable hunting areas by the Cooper's Hawk through the use of man-made perches. As there were no visual or auditory detections of the Cooper's Hawks, it is probable that local breeding populations do not reside near the orchards. According to the Michigan Breeding Bird Atlas (MBBA), the Cooper's Hawk have been detected in the northern Lower

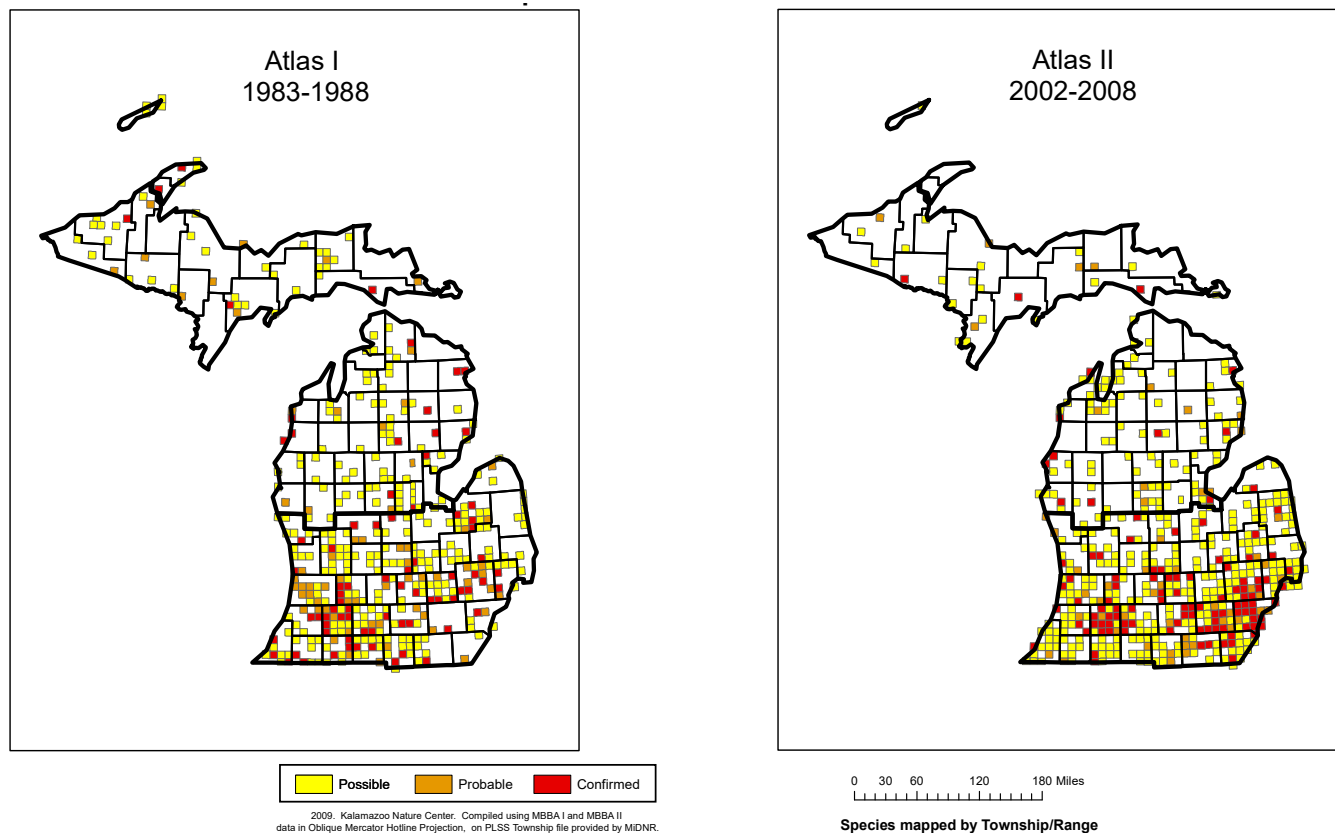


**FIGURE 1.** Species detected on perches. Species are listed in this figure by their four letter alpha code names; CHSP corresponds to Chipping Sparrow (*Spizella passerina*), BLJA to Blue Jay (*Cyanocitta cristata*), EABL to Eastern Bluebird (*Sialia sialis*), AMKE to American Kestrel (*Falco sparverius*), CEDW to Cedar Waxwing (*Bombycilla cedrorum*), and UNBI to unidentified bird.

Peninsula (NLP), although detections were few and widely distributed across the townships (Armstrong, 2011). Between the first (1983-1988) and second (2002-2008) publishing of the MBBA there was an increase in possible, probable, and confirmed Cooper's Hawk detections in Leelanau and Benzie counties, shown in Figure 2 (Armstrong, 2011). However, as the second MBBA was finished in 2008, it is difficult to know whether the populations are still increasing. It seems likely that Cooper's Hawk are uncommon enough that none happened to be residing near the study orchards at the time of the surveys.

Although the Cooper's Hawk were not recorded on the perch videos, other species valuable to fruit growers were recorded, including the American Kestrel, which eat many mammal, bird, and insect pests (Shave, 2017; Sheffield et al., 2001). Installing perches creates a more attractive habitat for American Kestrel (Shave, 2017; Sheffield et al., 2001). One of the American Kestrel recorded on a perch had a bird in its feet (a neonate killdeer, *Charadrius vociferous*) when it landed on the perch, suggesting that the perch was a useful addition to the orchard for the kestrel. Both kestrels were only recorded on the perches within the orchard, implying that the perches in the tree line are not as useful for them. The Eastern Bluebird, also considered valuable in reducing damage to fruit crops, were found on perch videos on multiple occasions. Bluebirds consume many insect pests; installing nest boxes in California vineyards increased insect predation by The Western Bluebird (*Sialia mexicana*) (Jedlicka et al., 2011). There was a nest box occupied by bluebirds in the

## Cooper's Hawk



**FIGURE 2.** Michigan Bird Breeding Atlas map of Cooper's Hawk sightings from 1983-1988 and 2002-2008 (Armstrong, 2011).

cherry orchard where they were recorded, so it is probable that the same bluebird pair occupying the box was using the perches. It is worthwhile to note that all of the sightings of bluebirds occurred over a period of five different days in June and July, and occurred 10 out of the 20 total times on one day. On multiple visits, the bluebird(s) deposited fecal sacs on the perch, suggesting they had just come from the nest box after removing the fecal sac.

While there may not be large breeding populations of the Cooper's Hawk in the study area, the speaker used to broadcast the calls may not have been loud enough to attract any that may have been in the area, especially if they were not within a small area surrounding the broadcast. As the broadcast only attracted two other raptors over the study period, speaker volume could be the issue. Increasing the broadcast volume may have yielded more positive detections of raptors, especially the Cooper's Hawk, if there are breeding populations in the area.

As there has not been a large increase in confirmed Cooper's Hawk populations in the NLP over the last few decades (Figure 2, Armstrong, 2011), and

there were no auditory or visual detections of the Cooper's Hawk over the study period, trying to use the Cooper's Hawk as a predator is not a realistic pest deterrent option in the NLP. However, perch addition may make orchards more attractive to the Cooper's Hawk in the southern Lower Peninsula, as there are well-established populations in that region (Armstrong, 2011). Additionally, perches may be a useful mechanism in attracting predatory birds other than the Cooper's Hawk to agricultural areas, as this study attracted two species that are beneficial to fruit growers to the perches.

## Acknowledgments

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# Influence of Hemodynamic Factors in the Assessment of Pulmonary Hypertension: An Image-Based, Computational Fluid Dynamics Study

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## Abstract

Pulmonary hypertension (PH) is a complex cardiovascular disease that is associated with elevated pulmonary arterial pressure, increased pulmonary vascular resistance, and decreased pulmonary arterial compliance. PH causes an increase in right ventricular workload, eventually leading to heart failure. Hemodynamic factors that may be associated with the pathogenesis and progression of PH include: wall shear stress (WSS), arterial stiffening, endothelial dysfunction, and the arterial resistance-compliance relationship. However, the main biochemical mechanism of PH development and progression in human patients is still unclear. In this study, we reconstruct a patient-specific pulmonary artery geometry and analyze arterial hemodynamic factors using computational fluid dynamics (CFD) to better understand the mechanics involved in PH. The geometric model of the pulmonary artery was obtained by phase-contrast magnetic resonance imaging (PC-MRI) and includes the main, left, and right vessels of the pulmonary artery. Initial resistance and compliance (RCR) boundary conditions were prescribed and calibrated in the model to match the clinically measured pressure waveform. Finally, a CFD simulation was used to analyze patient-specific blood flow patterns in the PH patient. Our results showed that changes in WSS, velocity, and pressure in the pulmonary circulatory system are associated with changes in pulmonary arterial hemodynamics. The mechanical property of a deformable wall, where the arterial wall dilates and constricts due to changes in arterial pressure over a cardiac cycle, will be implemented in ongoing research for a more accurate CFD analysis.

## Introduction

Pulmonary hypertension (PH) is a progressive disease that can arise as a result of multiple hemodynamic factors affecting and distorting the normal vascular geometry and mechanical properties, most notably affecting right ventricular function and workload.<sup>[5, 9, 11]</sup> Despite the recent advances in the treatment of PH, the major causes of the disease still remain unknown. Obtaining data to advance understanding of the disease often requires invasive procedures for PH assessment and diagnosis. Currently, when patients are suspected of having PH, they undergo right heart catheterization (RHC) for acquisition of diagnostic hemodynamic data.<sup>[5]</sup> However, computational fluid dynamics (CFD) can accurately and non-invasively analyze hemodynamics. Previous in-vivo computational studies have shown that the pulmonary vasculature is exposed to varying wall shear stress (WSS), suggesting that WSS could play an important role in PH progression.<sup>[5, 8]</sup> Specifically, computational models utilizing phase-contrast magnetic resonance imaging (PC-MRI) velocity data have revealed a reduction in WSS in the general PH population.<sup>[9]</sup>

Pulmonary artery flow, however, is not independent of the distal resistance and stroke volume of the right ventricle, and the current research proposes to couple CFD with prescribed resistance and compliance (RCR) boundary conditions that are associated with the distal pulmonary artery. The goal of this study was to use a new computational approach to iteratively adjust the resistance and compliance values of the simulated model until they match the clinically provided patient-specific data. This results in a calibrated model that provides a more precise analysis of WSS,

velocity, and pressure in the PH patient. The next section provides a background of the pulmonary circulation and hemodynamic changes in PH.

## Hemodynamics of pulmonary circulation in PH

The pulmonary circulatory system consists of three main components: the right ventricle (RV), the proximal pulmonary vasculature, and the distal pulmonary vasculature. The pulmonary artery, which only includes the proximal and distal pulmonary vasculature, is a crucial component in the cardiovascular system. The un-oxygenated blood ejected from the right ventricle flows through the proximal and distal pulmonary arteries, and into the corresponding lung. From there, the blood is oxygenated and transferred back to the heart where it is pumped through the aorta to the rest of the body.

Normal pulmonary arterial pressure is about 14mm Hg at rest. However, if the pressure rises to 25mm Hg or greater at rest and 30mm Hg during exercise, it is considered abnormally high. This threshold is often used as one of the criterion for diagnosing pulmonary hypertension.<sup>[12]</sup>

There are two major hemodynamic components of pulmonary arterial load: a steady component and a pulsatile component. Both depend on different parts and properties of the pulmonary artery tree.<sup>[3]</sup> The steady component of load can be represented by the mean pulmonary arterial pressure (mPAP), which is influenced by the caliber of small distal resistive arteries as reflected by the pulmonary vascular resistance (PVR). The pulsatile component of load is influenced by the elastic properties of the pulmonary artery tree, represented by the total arterial compliance ( $C_T$ ).<sup>[2]</sup> Therefore, PVR and  $C_T$  quantify the resistive and elastic properties of the pulmonary artery that modulate the steady and pulsatile components of pulmonary arterial load. Furthermore, although PH is classically viewed as a disease of the distal resistive arteries, the rise in right ventricle (RV) afterload results from an increase in PVR combined with total pulmonary arterial compliance.<sup>[2]</sup>

The normal pulmonary circulatory system is typically characterized by its low resistance and highly compliant vasculature with high distending abilities. mPAP is typically lower as it is proportional to vascular resis-

tance resulting in a more compliant pulmonary vasculature. However, in pulmonary hypertension, the right ventricular load increases due to an increase in PVR and a proportional decrease in total arterial compliance, ultimately leading to right ventricular failure. Therefore, the contribution of resistance and compliance are equally important in PH assessment and RV workload. Typically, PVR and total arterial compliance calculations are non-representative of their true vascular resistance or arterial compliance.<sup>[2]</sup> Thus, the present study prescribed resistance and compliance boundary conditions that were initially calculated by these methods. Then, after the initial computational fluid dynamics simulation, these parameters were calibrated to match the patient-specific pressure waveform data, which was clinically measured by right heart catheterization, at the outlets of the pulmonary branches.

## Pulmonary Vascular Resistance (PVR)

Physicians are familiar with the concept of PVR, which is a measurement of the extent to which the pulmonary circulation resists cardiac output (CO). PVR is mainly related to the geometry of small distal resistive pulmonary arteries. The major regulator of vascular resistance is the vessel radius, which according to Poiseuille's law, states that total vascular resistance is inversely related to the fourth power of arterial radius, which is shown in the following formula, where  $r$  is the arterial radius,  $\eta$  is blood viscosity,  $L$  is the length of the artery, and  $R_T$  is the total arterial resistance.

$$R_T = \frac{8\eta L}{\pi r^4}$$

In the present study, we used the total resistance formula and substituted it into Poiseuille's flow equation in order to obtain the following formula for total resistance<sup>[8]</sup> as shown below. This was used to calculate the initial proximal and distal resistance parameters prescribed to the CFD simulation.

$$Q_{mean} = \frac{\pi r^4 (mPAP)}{8\eta L} = (mPAP) * \frac{1}{R_T},$$

$$R_T = \frac{mPAP}{Q_{mean}}$$

Vascular changes to the arteriole diameter can result in a large increase in PVR and a reduction in arterial compliance, as found in PH patients. Therefore, PVR is considered to directly reflect the functional status

of pulmonary vascular endothelium and smooth muscle cells (SMCs). Altered PVR will result in endothelium dysfunction and SMC proliferation. In precapillary PH, increased PVR occurs as a consequence of proliferative remodeling and vasoconstriction of the distal pulmonary arteries in response to chronic pulmonary vascular injury.<sup>[2]</sup>

## Pulmonary Arterial Compliance

The normal pulmonary circulatory system is characterized as having low pressure and high compliance that can handle large increases in cardiac output. However, as seen in other studies<sup>[9]</sup> and concurrently in the PH patient in the present study, pulmonary arterial pressures increase in the proximal artery causing its diameter to increase, consequently lowering its compliant properties. In short, pulmonary arterial compliance is the measure of the pulmonary artery's ability to distend at a fixed vessel length. Typically, during the systolic phase of a cardiac cycle, blood volume and arterial pressure increase and result in a complete dilation of the artery when arterial compliance is normal. However, when arterial compliance is too low, the artery's ability to fully dilate is restricted despite the increase in blood volume and arterial pressure. Most likely, pulmonary arterial compliance decreases during hypertension due to an accumulation of the extracellular matrix protein, collagen, in the distal pulmonary arteries along with the degradation of elastin in the proximal pulmonary artery. In PH, this decrease in compliance results in a premature reflection of waves from the distal pulmonary vasculature, leading to increased pulsatile RV afterload and eventually RV failure<sup>[1, 10]</sup>.

$C_T$  can be viewed as the storage capacity of the entire pulmonary arterial tree and is defined as the increase in blood volume in the arterial system that produces a unit increase in arterial pressure.<sup>[4]</sup> During systole, a fraction of the ejected stroke volume is stored in the compliant pulmonary arteries, which is the equivalent to charging a capacitor in electronics. Then, during diastole, the blood stored in the compliant pulmonary arteries is released. The systolic storage of blood volume dampens pulsatile RV ejection and decreases both RV work load and mean RV ejection pressure.<sup>[2]</sup> However, in pulmonary hypertension, the pulmonary arteries compliant property is slowly reduced, thus increasing the RV work needed to pump blood through the distal arteries,

consequently increasing the pulmonary arterial pressure and decreasing the velocity flow rate in the proximal pulmonary artery.

Compliance can also be defined by the change in cross-sectional area over a given change in pressure at a fixed vessel length. It is commonly calculated as stroke volume (SV) over pulse pressure (PP), stated in the formula below.

$$C_T = \frac{SV}{PP}$$

However, this method of calculating total arterial compliance can overestimate the true value by 61% in some patients with suspected PH or congenital heart disease.<sup>[2]</sup> Therefore, this study sets compliance, along with proximal and distal resistance, as initial values that are iteratively adjusted to ultimately calibrate the simulated model parameters to exactly replicate the patient-specific pulmonary artery parameters that were clinically measured by right heart catheterization (RHC).

In the pulmonary artery, compliance decreases early in the pathogenesis of hypertension and is associated with vascular changes in response to active vasodilators.<sup>[4, 12]</sup> Initially, decreased pulmonary arterial compliance in PH was thought to be a proliferative vasculopathy, also known as a disease affecting blood vessels, leading to increased PVR and mPAP. In support of this hypothesis, increased mPAP does decrease total arterial compliance as a result of the nonlinear elasticity of the arteries.<sup>[6, 10]</sup> In other words, large deformations of the pulmonary artery vasculature cause increased mPAP and decreased arterial compliance. However, evidence now suggests that a loss of pulmonary artery compliance may actually initiate PH. In a recent study, patients with exercise-induced PH and those with mild pulmonary hypertension have reduced pulmonary artery compliance, despite a normal resting pulmonary pressure.<sup>[10]</sup> This indicates that compliance in the pulmonary vasculature changes early in the pathogenesis of PH, even when resting pulmonary pressures are within normal limits. In other words, a decrease in total arterial compliance can result from an increase in mPAP without a true change in elastic properties of the pulmonary arterial wall. Compliance can also decrease when the pulmonary artery wall stiffens due to a decrease in the elastin-to-collagen ratio as a result of vascular remodeling.<sup>[2]</sup>

It is very likely that vasoconstriction coexists with morphological changes, such as the disruption of the internal elastic lamina, and occurs before pulmonary arterial SMC hypertrophy and endothelial cell proliferation.<sup>[10]</sup> The impact on right ventricular function and the influential role in the development and progression of distal artery proliferative vasculopathy make it necessary to consider the pulmonary arterial compliance during the assessment of pulmonary hypertension.

## Resistance-Compliance Relationship

A common observation among recent studies is an inverse relationship between PVR and total arterial compliance in both healthy and hypertension patients. This inverse relationship has now been reported by numerous groups and is typically described by a hyperbolic fit, which means that an increase in PVR is followed by a decrease in total arterial compliance, and vice versa.<sup>[2]</sup> This increase in PVR will lead to an increase in pressure within the vasculature, which in turn reduces arterial compliance due to the nonlinear pressure-diameter relationship of the pulmonary arteries.<sup>[2]</sup> Therefore, it is possible that the prevailing mPAP is the main determinant of total arterial compliance, since arterial pressure directly influences the change of the artery's diameter. However, it is not the only contributing factor. Arterial resistance also influences mPAP<sup>[2]</sup> which then influences arterial compliance, proving that the resistance-compliance relationship is an important characteristic to any vasculature.

It is important to note that, unlike in the systemic circulation where arterial compliance is mainly localized to the aorta, total arterial compliance in the pulmonary circulatory system is distributed over the entire vascular bed.<sup>[7,11]</sup> However, the proximal arteries in the pulmonary circulation account for proportionally less of the total arterial compliance and arterial resistance as compared with the aorta in the systemic circulation.<sup>[2]</sup> The branches and distal arteries of the pulmonary artery account for the majority of total arterial resistance and arterial compliance.

## Methods

### Image Acquisition and Segmentation

In this study, a phase-contrast magnetic resonance

imaging (PC-MRI) of a single pulmonary hypertension patient was acquired from the National Heart Centre of Singapore. A three-dimensional model of the pulmonary artery of the patient-specific geometry was reconstructed from the PC-MRI. Reconstruction of the pulmonary artery vessel was achieved using CRIMSON, a cardiovascular integrated modeling and simulation software. Using vessel path editing, it was possible to trace the vessel by manually placing points within the lumen of the artery throughout multiple slices of the MRI scan. The software automatically connected those points and created a centerline through the lumen of the artery. Once the centerline was created, the next step was retrieving 2D contours of the vessel using vessel contour modeling. Lofting the contours and using vessel blending, a three-dimensional geometric model of the pulmonary artery (with contours that were blended at the bifurcation) was created. To improve the accuracy of creating and setting the complex geometry, a mesh was generated from CRIMSON meshing, where the arterial geometry was simplified and connected by smaller, tetrahedron components. The results of the computational fluid dynamics (CFD) simulation were calculated from the mesh by computing the relevant equations present at each point on the mesh. Once the segmentation and mesh generation were complete, CRIMSON allowed the user to set boundary conditions to the model. These boundary conditions are initial input values of mechanical and material properties applied to the model to simulate blood flow. Included in the boundary conditions were proximal resistance, distal resistance, and total arterial compliance values, a prescribed inlet velocity waveform over one cardiac cycle, and an assumed no-slip condition for the geometric model in this study. The inlet flow rate, shown in Figure 1, was measured by right heart catheterization (RHC) and the no-slip assumption created a rigid wall. After setting these parameters, a flow solver was created to implement the prescribed boundary conditions to the model in the CFD simulation. Figure 2 displays a flowchart of the segmentation and mesh generation of the three-dimensional model used in the CFD simulation.

### Prescribed RCR boundary conditions

In the CRIMSON software, hemodynamic conditions were applied at the outlets based on the Windkessel model, which shows the interaction between stroke volume and compliance in large arteries. Proximal

resistance ( $R_p$ ) was applied to simulate proximal pulmonary artery tone, a vessel capacitance ( $C$ ) was applied to simulate the compliant properties of the artery wall, and distal resistance ( $R_d$ ) was applied to simulate the arteriolar tone in the branches of the pulmonary artery (as shown in Figure 3). Total resistance in the pulmonary artery tree was calculated analogous to that in an electric circuit, with total resistance being calculated according to the equations derived from Poiseuille's flow equation and the fact that distal resistance accounts for a large amount of the total arterial resistance in the pulmonary artery. Therefore, the initial prescribed  $R_p$ ,  $C$ , and  $R_d$  were calculated using the following equations, where  $SV$  is stroke volume and  $PP$  is pulse pressure.

$$R_T = R_p + R_d,$$

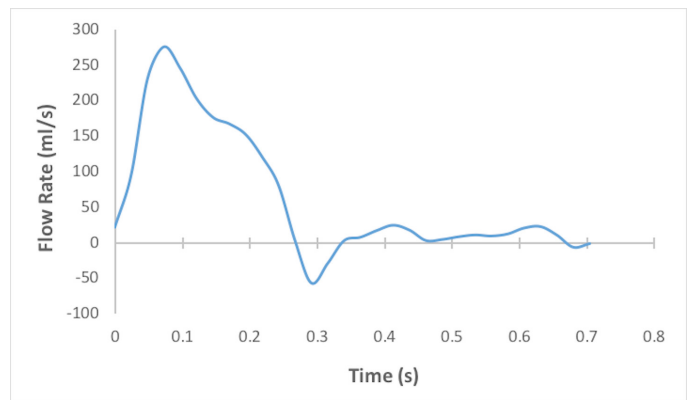
$$R_p = 0.056 * R_T,$$

$$C = \frac{SV}{PP}$$

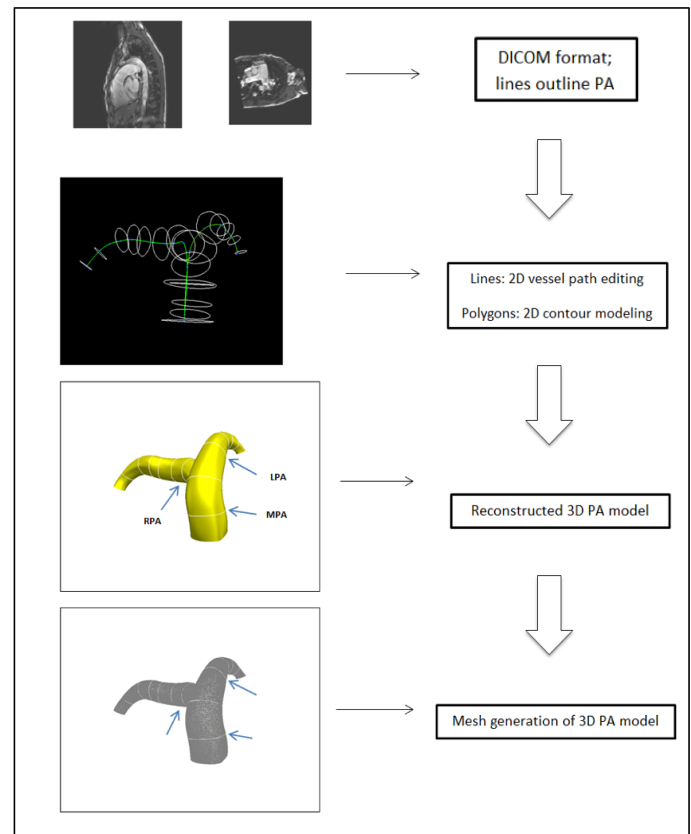
These calculations of total, proximal, and distal pulmonary arterial resistance were used as initial conditions in the CFD simulation, since they are estimates of the true values of arterial resistance and compliance.<sup>[2]</sup> The pressure waveform at each outlet was measured using the initial CFD simulation and the resistance and compliance parameters were calibrated to match the clinically measured patient-specific pressure waveform data. The new, and more accurate, RCR parameters were then prescribed to the geometric model for a more realistic simulation, thus achieving better results.

## Analysis of Hemodynamic factors

The CFD simulation on the reconstructed geometric model of the pulmonary artery was conducted using the CRIMSON software by creating a flow solver. CFD is a useful and noninvasive method to calculate and measure the blood flow in arteries. It provides numerical solutions for the analysis of blood flow patterns, spatial distribution of velocity, wall shear stress (WSS), and oscillatory shear index (OSI). Of these, WSS, pressure, and velocity were quantified in this study. These measurements have been used in previous studies for the analysis of disturbances in flow in the artery and also in correlating flow



**FIGURE 1.** PH patient-specific inlet volumetric flow rate over one cardiac cycle.

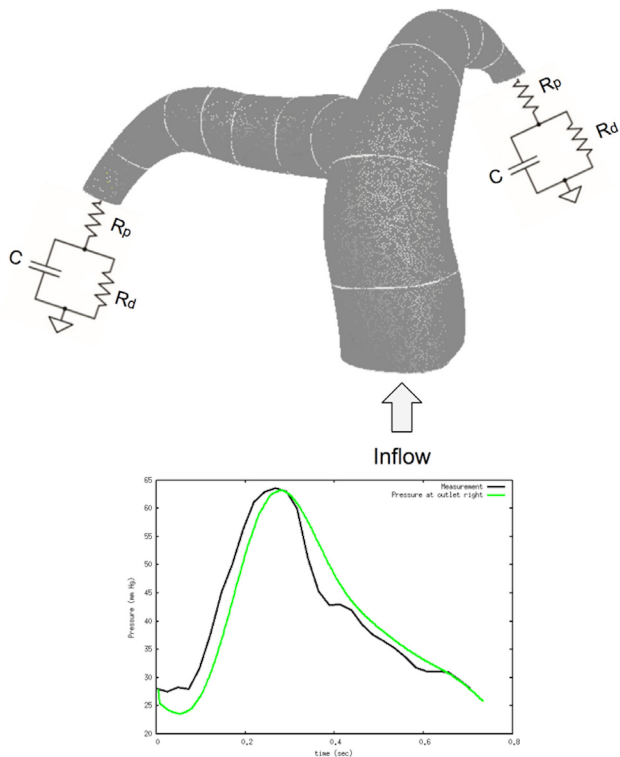


**FIGURE 2.** A flowchart detailing the reconstruction of the pulmonary artery from the PC-MRI into a geometric mesh used in the CFD simulation.

properties with vascular remodeling.<sup>[9]</sup> Essentially, other studies have found that by altering the blood flow patterns and properties in a particular artery, such as WSS and velocity, the artery's shape and structure can be directly altered. This process is more commonly known as vascular remodeling.

## Results

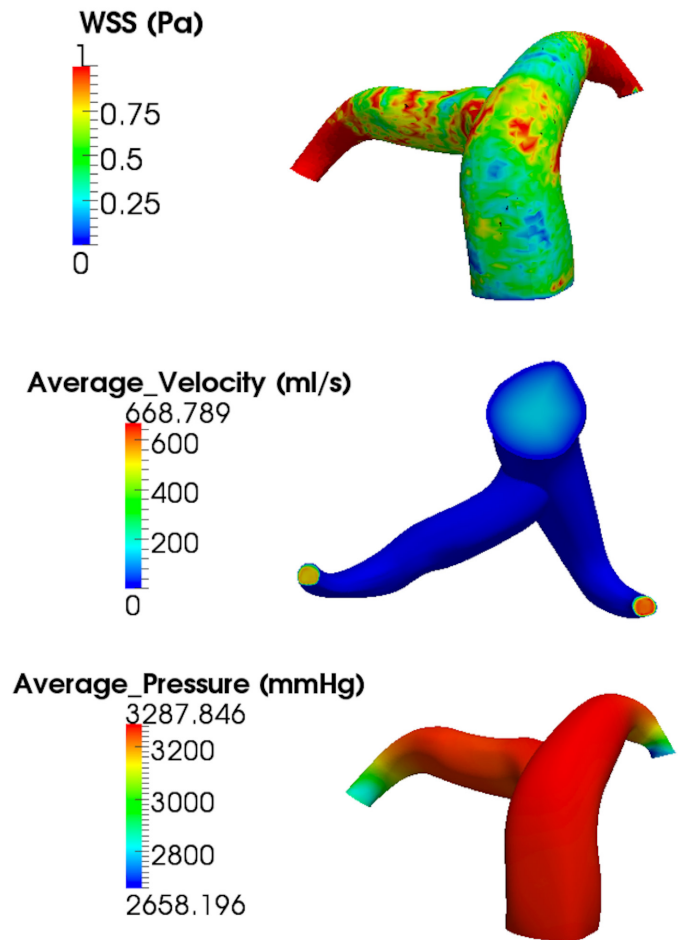
The reconstruction of the pulmonary artery from the phase-contrast magnetic resonance imaging (PC-



**FIGURE 3.** (top) A schematic drawing of the simulation setup showing the Windkessel circuit model of RCR outlet boundary conditions coupled with the 3D anatomical model. (bottom) Resulting pressure waveforms at the left and right outlets were tuned according to the patient-specific clinically measured pressure data. Shown is the pressure at the right outlet.

MRI) effectively depicts the patient-specific anatomy. Increases in diameter in the pulmonary vasculature are characteristic of arteries diseased with pulmonary hypertension (PH). Since pulmonary vascular resistance (PVR) is inversely related to the fourth power of arterial radius, increasing the diameter of the artery increases vascular resistance due to Poiseuille's law, which causes a reduction in the compliant properties of the pulmonary arteries. Therefore, as expected, and shown in Table 1, the PH patient was observed to have a larger main, left, and right pulmonary artery diameter than healthy patients. The PH patient diameter measurements were obtained from the reconstructed three-dimensional pulmonary artery model and are exact values. The healthy patient diameters were measured using the patient-specific MR images and correlated with population statistics.<sup>[5]</sup>

According to Poiseuille's law, the resulting force exerted on the arterial wall, the wall shear stress (WSS), is inversely proportional to the third power of the radius. This WSS is proportional to the arte-



**FIGURE 4.** Volume-rendered patient-specific CFD results displaying regional (top) wall shear stress, (middle) average velocity, and (bottom) average pressure in the proximal pulmonary artery and its branches.

rial velocity gradient and inversely proportional to the third power of the arterial radius. Therefore, low WSS, which was observed in the proximal artery of the PH patient in the present study, results from decreases in pulmonary artery velocity and increases in vascular diameter. Other studies have calculated WSS directly from PC-MRI data and have shown that it is typically low in patients suffering from PH.<sup>[5]</sup>

WSS, average velocity, and average pressure were measured from the computational fluid dynamics simulation and are displayed in Figure 4, which shows the patient suffering from PH. As expected, results from the computational fluid dynamics (CFD) simulation display lower WSS, lower average velocity, and higher average pressure in the proximal pulmonary artery. However, in the pulmonary branches, results displayed higher WSS, higher average velocity, and

**TABLE 1.** Patient-specific diameter measurements. MPA: main pulmonary artery; LPA: left pulmonary artery; RPA: right pulmonary artery. Healthy patient data retrieved from reference 9.

	MPA	LPA	RPA
Healthy patient	2.7 +/- 0.1 cm	2.0 +/- 0.2 cm	1.9 +/- 0.2 cm
PH patient	3.09 cm	2.32 cm	2.22 cm

lower average pressure as the diameter decreased. The high values of WSS were not expected for the pulmonary artery branches and are most likely due to the reconstructed model only containing two branches. Normally, there are branches that stem from both the right and left pulmonary arteries before the outlets in the current model. Therefore, WSS and velocity were observed to increase where they are expected to decrease due to a flow split. As shown in Figure 4, a larger proximal pulmonary artery, along with a lower flow rate in the PH patient, leads to lower velocity magnitudes flowing through the proximal artery resulting in lower WSS.

## Discussion

The objective of this study was to perform computational fluid dynamics simulations to analyze hemodynamic factors which affect wall shear stress (WSS), velocity, and pressure throughout the pulmonary vasculature of a pulmonary hypertension (PH) patient. This study also investigated the accuracy of common measurement techniques of total resistance and total compliance and incorporated the use of patient-specific pressure waveforms from the pulmonary artery. Resistance and compliance (RCR) boundary conditions calculated from commonly used equations were prescribed to the model for the initial computational fluid dynamics (CFD) simulation. After the initial simulation, the RCR parameters were calibrated to match the patient-specific pressure waveform data and then prescribed into the final CFD simulation. This method provides a more accurate analysis of WSS, velocity, and pressure in the pulmonary artery. Furthermore, we found that the CFD simulation results can be strongly correlated to the hemodynamic factors in the pathogenesis and progression of PH. Phase-contrast magnetic resonance imaging (PC-MRI) and CFD data were combined to visualize and quantify

patient-specific hemodynamic conditions in the proximal pulmonary artery and its branches. These included WSS, average pressure, and average velocity, all of which are influenced by arterial resistance and arterial compliance. For a healthy subject, the patient-specific magnetic resonance images are available and were provided by the National Heart Centre of Singapore. However, the geometry and the clinically measured patient-specific pressure waveform were not available for this study. Therefore, the hemodynamic factors of the healthy subject, such as pressure and velocity waveforms over a cardiac cycle, are based on population statistics,<sup>[5]</sup> and the time-dependent comparison of PH hemodynamic factors with those of a healthy patient was not able to be made.

Intuitively, an increase in distal pulmonary vascular resistance (PVR) and in arterial compliance would suggest an increase in upstream (proximal) arterial pressure. In PH, increased resistance and decreased compliance in the artery's branches cause an increase in pressure and arterial remodeling in the form of increased arterial stiffness in the proximal vasculature,<sup>[5]</sup> as shown in Figure 4. Previous research has found valid and strong correlations between pressure and compliance, and even stronger correlations between pressure and distensibility.<sup>[5]</sup> Therefore, with reduced compliant properties, the artery stiffens and the distensibility of the artery decreases according to the pressure increase observed in the PH patient. Increased pressure and arterial stiffness are known to contribute to increased cardiac workload and right ventricle afterload, which results in the lower average velocity and WSS as seen in the proximal pulmonary artery in Figure 4.

Consistent with previous findings, we found that the pulmonary vasculature of patients suffering from PH is exposed to a WSS that is reciprocal to disease



severity, as assessed by PVR and arterial compliance.<sup>[5]</sup> In other words, lower WSS correlates with PH progression, and vice versa, for healthy patients. This finding is generally calculated. Given Poiseuille's flow equation, we would expect a local constriction of the vasculature to increase the WSS and local dilation to reduce the WSS. The results of the present study observe the PH patient experiences increased WSS in the distal regions, where the artery is constricted, and reduced WSS in the proximal region, where the artery is dilated. The strong relationship between WSS and PVR, and the fact that experimental PC-MRI data reveals lower WSS in PH patients, suggests that the increased resistance and decreased compliance that result from the constriction of the distal pulmonary vasculature, will alter the local velocity profiles in the proximal pulmonary artery.<sup>[5]</sup> This explains the lower average-velocity and reduced WSS seen in the proximal pulmonary, which is expressed in the PH patient in this study. Reduction in WSS, commonly seen in PH patients in other studies,<sup>[9]</sup> could be a result of decreased cardiac output (CO) from the right ventricle.<sup>[5]</sup> This could be due to increased afterload influenced by decreased compliant properties in the pulmonary vasculature, causing a lower velocity flow rate. However, this was not extensively investigated in this study.

WSS in the pulmonary vasculature is simply a reflection of local hemodynamics, driven by the inflow and outflow RCR boundary conditions and vascular geometry. Therefore, hemodynamics could be a better indicator of ultimate vascular remodeling because it reveals the flow conditions acting on the endothelium during disease progression.<sup>[5]</sup>

Clinically, the assessment of WSS by use of an MRI according to arterial resistance and arterial compliance, along with other hemodynamic factors mentioned in this study, such as arterial stiffness, may lead to early detection of pulmonary hypertension. It may also contribute to the efficiency of existing and newly emerging therapies for treatment of the pulmonary hypertension disease.

One major limitation to this study was that the results found were based on a single PH and a single healthy subject. This may cause a discrepancy if the results are applied more generally. Therefore, in future work, we aim to continue the use of non-invasive imaging and CFD techniques with a larger

population of healthy and pulmonary hypertension patients to compare their differing hemodynamics. It will be essential for future studies to obtain healthy patient geometries to more accurately represent the healthy patient population and their corresponding hemodynamic factors when compared to pulmonary hypertension patients. This is necessary to determine the practicability and clinical applicability of multiple varying methods used in the assessment and diagnosis of pulmonary hypertension.

## Acknowledgments

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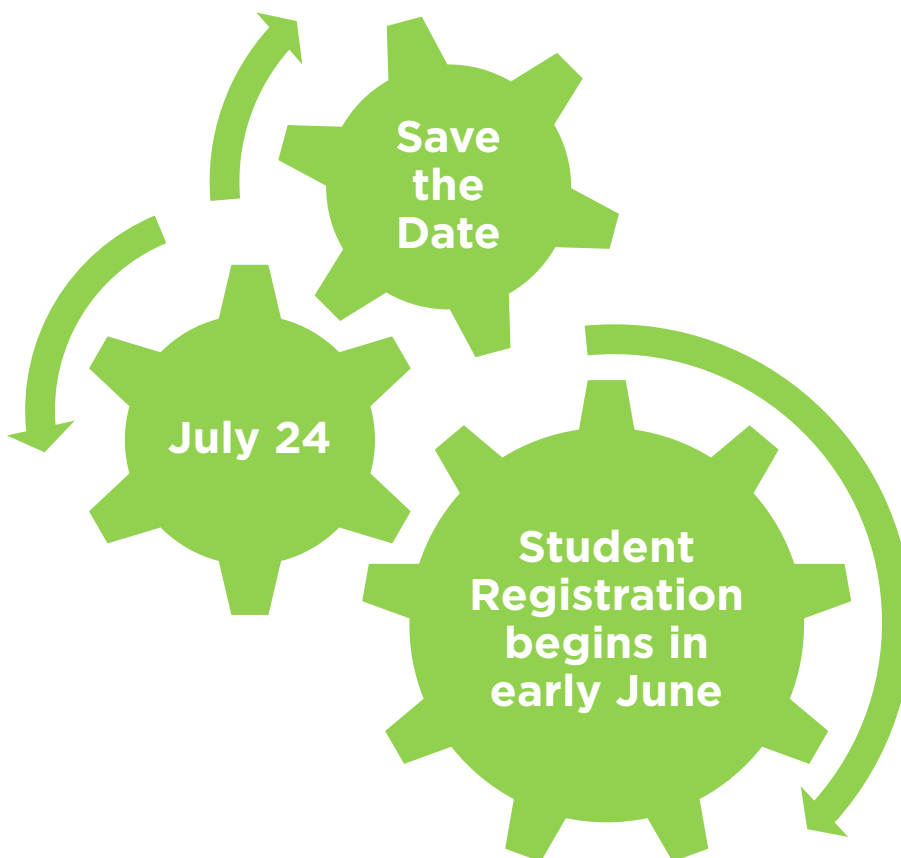


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# Bobby Sands and the Construction of Irish Republican Identity in Long Kesh Prison

Brigid Kennedy | James Madison College

## Abstract

This research analyzes the works of Bobby Sands to examine the creation of an Irish rebel culture in Long Kesh Prison during his internment in the second half of the 20<sup>th</sup> century. Sands' writings from prison, as well as his hunger strike, use the rhetoric of prior iterations of Irish Republican resistance to English colonial rule in order to create a sense of continuity in the movement. The nature of the differentiation of the Irish rebel community from the Irish as a whole has significant implications for the success of the tenuous post-Troubles peace in Northern Ireland today. The rebel culture that developed in Long Kesh Prison is still at work, particularly in urban areas, isolating dissident Republicans from other communities to which they belong.

## Introduction

Bobby Sands' writings serve as a striking representation of the construction of a unique "nationality" for the prisoners in Long Kesh in the 1970s and 1980s, one that is fundamentally different from both British and Irish culture. There are key differences in the Irish language spoken inside and outside of prison,<sup>1</sup> which shows that the rebel community differentiated itself from the rest of Ireland. The prisoners in Long Kesh did not feel a sense of solidarity (which was necessary for ethnic communities<sup>2</sup>) with the Irish who did not rebel, which explains the unintentional and disadvantageous split between the Irish rebels and those they saw as merely Irish. The Irish rebel identity relies on the apotheosis of prior resisters and the rebels' view of themselves as heirs to the Irish identity in its purest form as displayed by past generations of the movement. This rebel identity in Long Kesh Prison is embodied in Sands' writings and legacy. This research uses *Diarmait Mac Giolla Christ's Jailtacht: The Irish Language,*

*Symbolic Power and Political Violence in Northern Ireland, 1972 – 2008* as a basis, and seeks to expand on Mac Giolla Christ's understanding of Irish language learning as a form of cultural rebellion by specifically examining Sands' prison writings.

## History

Irish (*Gaeilge*), one of six Celtic languages, has experienced a significant decrease in popularity during England's rule of Ireland.<sup>3</sup> Since the signing of the 1921 Anglo-Irish Treaty, Ireland has been embroiled in conflict regarding which nation should control the northern six counties (Northern Ireland). As tensions wax and wane, culture and language become weapons and must be viewed politically. One of the most significant developments in the conflict in the last fifty years has been Republican internment in Long Kesh Prison. Originally a Royal Air Force base during World War II, in 1972 Long Kesh became a prison used by the British to keep Irish political figures prisoner. Originally, interned Irish Republicans were kept in the "Cages," a set of huts.<sup>4</sup> In 1976, however, most of those interned lost their status as political prisoners and were moved to the newly constructed "H Blocks," also located at Long Kesh, which more closely resembled a traditional prison.<sup>5</sup> Because the prison concentrated Republicans, Ireland's ideological and ethnic conflicts were concentrated there, too—so much so that Northern Ireland's Irish language revival is now almost synonymous with Long Kesh.<sup>6</sup> The circumstances and politicized nature of the language revival point to the divisiveness that defines the Irish language still today.

Sands joined the Irish Republican Army (IRA) in 1972 at the age of 18, a few weeks after his family was driven from their home in Rathcoole, North Belfast by Loyalists.<sup>7</sup> One month later, "he was charged with possession of a weapon found in a house and

sentenced to three years in Long Kesh.”<sup>8</sup> During his first internment, Sands stayed in Cage 11 as a political prisoner, where he learned to speak Irish from Cyril McCurtain, who had also been interned in the 1950s.<sup>9</sup> After a short release, he was once more arrested when a gun was found in a car in which he was a passenger; he was sentenced to fourteen years, also to be served at Long Kesh.<sup>10</sup> Sands went on to be elected to Parliament from inside prison, running on the ticket of “political prisoner” for Fermanagh and South Tyrone<sup>11</sup>—an indication of how dominant his identity as a rebel (political prisoner) had become.

## Findings

In 1981, Sands led his fellow prisoners on a hunger strike in response to a set of policies referred to by Republicans as “criminalization.” The British government had removed the “special category” status for most of the Irish political prisoners, which meant that they were, for all intents and purposes, simply criminals in the eyes of the law. Removing special category status meant that prisoners could be treated differently. They were moved from the Cages to the H Blocks and given far less control over their own affairs, including the processes like prisoner-organized education that were crucial to maintaining the rebel identity in Long Kesh. The implications of their imprisonment were also changed—being a political prisoner is not shameful in the way that being a “criminal” is, and being a rebel was a source of distinction and pride for internees. Sands became emblematic of the Irish Republican movement of the 1970s and 1980s through the publicity he gained from his hunger strike at Long Kesh. His writings were smuggled out of prison, offering a rare contemporary perspective on Irish Republican internee communities. As a result of his hunger strike in Long Kesh, Sands died on May 5, 1981.

The strike was about more than securing certain rights. The action of a hunger strike is evocative of many facets of Irish rebel culture, and its use in 1981 was no coincidence. By choosing a hunger strike as his act of protest, Sands was drawing on pre-Christian Irish civil code, the Brehon Laws, in order to make a case against England. The hunger strike, known as *cealachan* or *troscéad*, was part of the law of *Athgabhail* (Distress), which allowed a person who had been wronged to fast “at the door of the

wrongdoer,” leaving “responsibility for ending the fast... vested in the perceived wrongdoer.”<sup>12</sup> These laws were also revived in W. B. Yeats’ 1905 play “The King’s Threshold.” There, Yeats tells the story of how a man who thinks he is wronged can “starve upon another’s threshold till he die,” and “The Common People, for all time to come / Will raise a heavy cry against that threshold / Even though it be the King’s.”<sup>13</sup> Sands’ death, at the prison eventually called *Her Majesty’s Prison the Maze*, was symbolically at the Queen’s threshold. Even in Irish Catholic tradition, “many members of the clergy” and “even Ireland’s patron saint, St. Patrick, went on a hunger strike against God. After forty-five days, so the story goes, God eventually backed down.”<sup>14</sup> Sands planned his death to be a cultural weapon, and one that placed him securely into a community of rebels and resisters.

The use of Irish as a language in Long Kesh had a lot to do with power. Prisoners, especially those in the H Blocks, had little control over their lives. Speaking Irish allowed for a collective group identity, something they could use to “set themselves apart from the prison officers.”<sup>15</sup> Not only was Irish a way to separate internees from prison authorities, it gave internees a way to fight back against the British Empire itself. “We recognized the lengths the imperialists went to destroy the language and from this reasoned that it must be important. When you look at imperialists all over the world the first thing they try and do is destroy the culture of the nation and attempt to replace it with their own as it makes people easier to manage!”<sup>16</sup> one internee said. For many, a revival of the Irish language meant a revival of Irish culture, and a revival of Irish culture meant a diminishing of English culture. The symbolic power associated with language is great: “Attempts to bring about, or to resist, social ideological homogeneity are conducted through the manipulation of language,”<sup>17</sup> in part because language is “the most obvious source of tribal identification.”<sup>18</sup> Language is one extremely simple way to limit a community because other forms of connectedness are almost impossible without a common language. The Irish language that developed in Long Kesh was significantly different from the Irish language outside, so much so that it became known as “Jailic” (a play on “Gaelic”)<sup>19</sup> because all classes were taught from (often distorted) memory.<sup>20</sup> This language division, however unintentional, further solidified differ-

ences between the prisoners and the rest of the Irish people, especially because usage of the language continued to decline outside of prison. In Long Kesh, the Irish language helped internees keep their identities in the prison environment and create a new collective identity that continued to exist even after the prisoners' release.<sup>21</sup> The Irish language taught in Long Kesh is dialectically different from the Irish spoken just outside the prison walls. Today, these linguistic differences remain, although Long Kesh does not. Members of the IRA and other active resisters were more likely to be interned than other members of the community, so the linguistic division often signifies a political division as well. Members of ethnically Irish communities in Northern Ireland can identify the most active resisters to British rule simply from the Irish they speak. Internment policies and subsequent identity formation for prisoners in Long Kesh created lasting divisions in Irish communities in Northern Ireland.

Sands believed that the H-blocks were designed to crush the internees' political identity,<sup>22</sup> and their response was to create an even stronger identity. Sands said his fellow prisoners could bring down the British Empire, saying that "H Block is the rock that the British monster shall perish upon."<sup>23</sup> Because internment had been a policy in Ireland in earlier conflicts, many prisoners in Long Kesh, including Sands, learned Irish from people who had been interned in the 1950s, and those internees learned Irish from prisoners older than them. Having successive generations of prisoners in contact with one another allowed the rebel community to attain a sort of continuity that is necessary to give the group the "shared historical memories" that build an ethnic community.<sup>24</sup>

One of the most significant breaks between the larger Irish culture and the Long Kesh community was education. The internees organized their own education of both Gaelige and other subjects, such as the history of the Republican movement.<sup>25</sup> In Long Kesh, Sands focused on teaching Gaelige to others, and Gerry Adams remembers him as one of the best teachers in the prison.<sup>26</sup> Sands saw language education as extremely important both inside and outside of prison, and his earliest confirmed writing in Irish, *An Bunadh Gaeltachta*, circa 1975, was a plea for more Gaeltacht (Irish-speaking) regions to be set up near Belfast. His concern with the ability of

Irish people in general to speak Gaelige likely stems from his belief that speaking Irish is directly related to a cultural resistance against the British, and thus he hoped to spread a rebel identity. In many of his writings, Sands separates the Irish from Irish rebels, and language is one of the factors he uses to separate these groups. In Long Kesh, where learning Irish language was an expression of resistance, it defined the community in salient ways.

In a great majority of Sands' writings, English is the predominant language, with bits of Irish sprinkled in (in the form of salutations and interjections). One of the likely reasons he did this was because it's easier for the reader to learn these words—they're used repeatedly in similar situations. The reader can understand the context in English and, after having seen the Irish a few times, understand the basic meaning of a phrase. Sands himself didn't learn Irish until his first period of internment at Long Kesh, so he would not expect every sympathetic reader to speak it. He made his writings accessible to the English speaker but strategically began to draw the reader into the community of Gaeligeoirí (Irish speakers), and thus, in Sands' mind, also into the community of rebels.

The phrase *mo chara*, or *cara*, is an important example of a phrase popular in Long Kesh that defines the community there. Originally meaning "friend," *mo chara/cara* gained a meaning closer to "comrade" in Long Kesh,<sup>27</sup> which signals the movement's socialist undertones. Sands also uses this term to give anonymity to his IRA contact on the outside.<sup>28</sup> It is important to note, then, that the term is only applied to fellow resisters: Sands uses it to define the boundaries of the rebel community. Members of the IRA and fellow internees are referred to as *cara*, a term of endearment specific to their identity, and by changing its meaning slightly they make it their own.

One of the most important phrases to the Irish Republican movement is *tíocfaidh ár lá*, meaning "our day will come." Its first known use in English is in James Joyce's heavily political novel *Portrait of the Artist as a Young Man*, in a scene in which characters discuss resistance to British colonialism.<sup>29</sup> Its translation to Irish, however, is attributed to Sands.<sup>30, 31, 32</sup> *Tíocfaidh ár lá* is improper given the rules of Irish grammar,<sup>33</sup> so there are three possibilities:

Sands made a mistake, the phrase is proper in the Long Kesh variation/dialect of Gaeilge, or Sands intentionally formatted the phrase in this way. The sentence formulation matches that of English,<sup>34</sup> so I believe that Sands put together the phrase in this way to make it easier to understand for the native English speakers he hoped to draw into the rebel community. Mac Giolla Christ argues that there is violence inherent in the phrase because its first use is described as “shattering the silence like the impact of a brick crashing through a window” and having “bitterness and hate rivetted [sic] to every single syllable.”<sup>35,36</sup> Its use once again accompanies the idea of violence in a short story of Sands’ in which an internee is tortured by prison authorities (“screws”), and the character uses the phrase while “mentally killing all sorts of screws.”<sup>37</sup> *Tiocfaidh ár lá* remains today an important part of the mythology of the rebel identity, so perhaps its association with resistance relates it inextricably to violence.

In his poem “Dreamers,” Sands draws on Celtic heritage and Irish nationalism, especially through his use of the term *bearna bhael*. This phrase, too, is a misspelling of *bhearna baoil*, though I believe this mistake is unintentional (since *bhael* and *baoil* could be pronounced similarly given the context). The Irish national anthem contains the lines “*Anocht a théam da bhearna baoil, le gean ar Ghaeil chun báis nó saoil*,” which I translate (differently than the official English version of the anthem, for clarity’s sake) roughly to “tonight we man the breach, for Ireland we die or live.” In the poem, Sands describes characters of Irish myth and history fighting together with the Irish people.<sup>38</sup> Among those fighting are Cú [Chulainn], Aodh Rua[dh], Aodh [Mag Uidhír], and Aodh Ó Neill, all of whom he describes as “once again [falling] to woe.” His use of the word “woe” may also reference the Irish anthem, since what I translate as “death” is translated in the traditional English version of the song as “woe.” The national anthem, “A Soldier’s Song,” was originally a song used by nationalists in the Anglo-Irish War and thus well within the limits of the rebel identity, so Sands’ reference to it and rebel heroes becomes part of his larger plea for more Irish people (who would recognize a reference to their anthem) to join the rebel community.

In “The Rebel,” Sands uses the Irish language, history, and legend to separate the English, the Irish

people, and the rebels. He references the “lord of the manor sat upon a black bloody deed,” which represents the English (and those who were given land that belonged to the Irish). The only words written in Irish are those that directly represent the Irish people—the *slua sí* (fairies) and the *Rí na síogaí* (king of the fairies). In the poem, a woman with a “green body glistening in the silvery rain” represents Ireland, and the *slua sí* had been with her to listen to a minstrel (the rebel) and a mistle thrush who sing “of a land yet unfree” (in an act of rebellion). The minstrel is killed by the lord, and the *slua sí* bury him next to “a lonely blue bell.” The fairies do not all have the capacity to act as the rebel minstrel, but they weep for him at his death, much as Irish culture has rallied around men like the leaders of the Rising—or Sands. Thus, the minstrel is part of Sands’ rebel community. The bluebell is also significant in this poem. Later in his writings, Sands describes bluebells as being like “oppressed, impoverished people ... for they stand so humble, their heads dropped lest they offend the towering, ugly brambles and weeds—the parasites of nature.”<sup>39</sup> Bluebells, too, represent the oppressed and impoverished Irish people. Bluebells become a sign of strength for Sands, not just when the minstrel is buried next to one, but in a poem entitled “Comrades in the Dark.”<sup>40</sup> In this poem, Sands describes roses, the “garden’s joy,” being plucked from the garden by soldiers, and imprisoned in “dank cold cells.” In the poem, the roses have such a strong desire for freedom that they become “the light to guide the poor,” and eventually even the “humble bluebells lift their heads, to rise in all their power.” The bluebells, like the *slua sí*, represent the majority of the Irish in Sands’ eyes—the people who do not know how to rebel and thus stay quiet and subservient. Sands’ poems show that he viewed the rebel community as the minstrels and the roses, the people who would guide and teach the bluebells to rise up and become rebels themselves.

A common thread throughout Sands’ writings from prison is his use of birds as allegories for different groups in the conflict. In his March 13, 1981, diary entry, written mainly in Irish, he says, “*Uaigneach abhí mé ar feadh tamaill ar tráthnóna beag inniu ag éistacht leis na preácháin ag screadáil agus ag teacht abhaile daobhtha. Da gclúinfinn an fhuiscog álainn, brisfeadh sí mo chroí*,” which translates to “I was lonely for a while this evening, listening to the crows caw as they

returned home. Should I hear the beautiful lark, she would rent my heart.”<sup>41</sup> Because this passage is written in Irish, it is significant that Sands points to a language difference of sorts between the lark and the crows. Sands is lonely at the sound of cawing crows because the crows do not represent his community. The lark, however, is a symbol Sands uses both for himself and for Northern Ireland. In “The Lark and the Freedom Fighter,” he tells of a lark imprisoned in a cage who refused to sing, so its owner “starved it and left it to rot in a dirty cage.”<sup>42</sup> Sands directly compares himself to this lark and its spirit of resistance, then compares other hunger strikers throughout Irish history to larks as well. He identified so strongly with the lark that for many of his writings for *An Phoblacht*, the Sinn Féin newspaper, he uses the pseudonym “an fhuisseoig,” the lark.<sup>43</sup> He characterizes England as a bird, as well. In “The Window of My Mind,” Sands says that “the ruler of the kingdom” he can see from his window “is the seagull, who dominates, steals, pecks, and denies the smaller birds their share. The seagull takes it all. In fact, his appetite is insatiable. He goes to any length to gorge himself. Thus I dislike the seagull, and I often wonder why the starlings do not direct their attention to the predator, rather than each other.”<sup>44</sup> Importantly, in this passage Sands clearly not only sets himself aside from the seagulls (the British), but he once again sets himself aside from the Irish (starlings) who do not fight or who fight the wrong enemy—a reference to some paramilitary activities. His observations are from a position outside of either group. Sands clearly considers himself Irish, but this is evidence that he first considers himself part of a distinguished group within the Irish community: the rebel community. As a rose, a minstrel, and a lark, it is his duty to guide the bluebells, *slua sí*, and starlings out of their oppression.

Sands’ final work, a diary entry written on St. Patrick’s Day,<sup>45</sup> ties together several symbols of Irish culture to create a plea for more Irish people to join the community of rebels. This entry is written entirely in Irish, and it ends with a strong rhetorical appeal to the Irish people to join in the struggle. Translated into English, he says, “If they aren’t able to destroy the desire for freedom, they won’t break you.... The day will dawn when all the people of Ireland will have the desire for freedom to show. It is then we’ll see the rising of the moon.” These last words reference a rebel song, “The Rising of the

Moon,” about the 1798 Rebellion. The song describes a loss in battle, but asks future generations to revolt again (“Who would follow in their footsteps at the rising of the moon?”).<sup>46</sup> In his last written words, Sands is asking the Irish people to follow him in rebellion, just as the song does. He believes that only once everyone is willing to work for freedom will freedom come. Sands was alive for more than a month after writing this, so I believe that he stopped his diary here to be completely sure these would be recorded as his last words, written on a holiday celebrating a national figure who was successful in his hunger strike. Sands hoped that through his death, the Irish would realize they had the power to rise up once again.

Sands’ hope for a resurgence of Irish cultural resistance in the wake of his death was, in fact, realized. A 1985 study, which sought to explain the “dramatic growth in interest in the Irish language” in West Belfast found that 33% of respondents cited the Republican movement in general as the reason for the revival, and 5% cited Sands specifically as the reason they began learning Irish.<sup>47</sup> Sands’ writings and death provided the impetus for the popular politicization of the Irish language in the service of the Republican movement.

## Discussion

During the Troubles, the physical separation of prisoners from the general public and the perceived differences in ideologies of the two groups led to a division between rebels and non-rebels. The groups spoke differently and had different ideas of what it meant to be Irish. The rebel community perceived a lack of public support and thus claimed for itself the mantle of Irish Republicanism, the success of which hinged on receiving more public support. Sands’ writings from inside Long Kesh prison are invaluable resources in analyzing the rhetoric that the rebel community used to win support because of the role Sands played in distinguishing the pure rebel identity from the common Irish identity. The implications that this separation could have for modern politics in Ireland are immense and can lead to further radicalization of Northern Irish politics on all sides, as well as to an extension of the cycle of struggle that has played out in Ireland for hundreds of years.



## Acknowledgements

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# Mentors Make All the Difference

Alan Lesgold | The University of Pittsburgh

After 45 years of being a professor and a dean, I've come to realize that many helpful mentors catalyzed any later career successes. It all started at Michigan State. I entered the MSU Honors College in its eleventh year. This allowed me to take a mix of graduate and undergraduate courses, skip such things as introductory psychology as I pursued a psychology major, and otherwise learn a lot in a more rigorous environment. It also set the stage for mentoring that shaped my career.

Knowing that college costs were a strain for my parents, I worked throughout my undergraduate years. Initially, MSU provided a job in the dormitory food service, feeding food waste to the world's largest garbage disposal. After a few weeks, I was pretty sure that I had learned about as much as I could from this particular job, though it really was not all that bad (the young are less prone to dishpan hands). About that time, I saw a small ad in *The State News* placed by Professor Charles Wrigley, a political psychologist who, with Dean Louis McQuitty, had formed the Computer Institute for Social Science Research. The ad indicated that there were jobs for Honors College students in which they would be trained to do computer programming. I thought this would be more fun than the dish room.

I remember a few things about my initial interview with Wrigley. He was from New Zealand and had a British education, but his knowledge of how MSU students lived was a little sketchy. When I told him I worked in food service, he said, "So, your job is to take pies out from the kitchen to the students?" I filled him in on the technological depths I actually had reached. He then explained that he was hoping that I could join some graduate students in the task of writing programs to do multivariate statistical analyses (the stat packages we all use today did not yet exist). Specifically, he was interested in doing factor analyses of a large body of data collected about early Peace Corps volunteers. He then took a pad of paper and explained the basic ideas behind factor analysis to someone who had no background in statistics or linear algebra. Amazingly, it all made sense, and I was able to follow his explanations.



Alan Lesgold is professor and former Renée and Richard Goldman Dean (2000-2016) of the School of Education at the University of Pittsburgh and professor of psychology and intelligent systems. He is a 1967 graduate of Michigan State University and alumnus from the Honors College. **Courtesy Photo**

For the remainder of my undergraduate days, I worked in Wrigley's institute. The core task we pursued—and I was one of many involved—was to write a package of software to do multivariate statistics. So, my undergraduate job ended up teaching me computer programming and multivariate statistics at the cost of limiting my expertise in quickly removing peanut butter from dishes before they went through a dishwashing machine. My mentor from day-to-day in this effort was Frank Sim, a graduate student in sociology. I also learned a lot about scaling from McQuitty, who did some of the pioneering work in cluster analysis. And of course, Wrigley was a wonderful first mentor.

There was another experience that occurred as a result of my work in the Institute. In 1964, when I was a sophomore, I was asked to teach a course for high school students in FORTRAN programming. This was my first teaching experience, and it went reasonably well, I think. A couple of years later, a national magazine had an article suggesting that this was the first programming class ever for high school students, but I am pretty sure someone at MIT had done it earlier. Overall, Michigan State provided incredible opportunities. I got a good grounding in psychology, including some graduate courses. I learned the essentials of multivariate statistics and scaling. I learned both how to program and that I was quite capable of getting computers to do things. That confidence in my abilities was as important as the specific knowledge and skills I gained.

By the time I finished my undergraduate degree at MSU, I was well positioned as a potential research apprentice. Graduate work at Stanford University was followed by a faculty position at the University of Pittsburgh, where I remain a professor. The great start at MSU and all of the mentors along the way allowed me to move from psychological research to developing intelligent tutoring systems to teach workers complex technical jobs to becoming the dean of the University of Pittsburgh's School of Education. Each step along the way was facilitated by selfless mentors who built on the foundation I got from Wrigley. Hopefully, I have been able to help a

few young scholars begin or continue great careers along the way. If you want to know about my many later mentors, please see a recent article in Education Review: <http://edrev.asu.edu/index.php/ER/article/view/2139>.

Each mentor helped me handle a hard task; collectively, they provided the scaffolding I needed to do some pretty interesting work, including early work on medical expertise, developing one of the first successful intelligent tutoring systems, and being a pretty effective dean. While most of my mentors were academics, there were a few others who helped as well. Sharon Bower, the wife of my dissertation advisor Gordon Bower, taught me how to make effective oral presentations. And, of course, my wife Sharon Lesgold provided both moral support (often needed) and wisdom about mathematics education.

Without those first mentors at Michigan State, I would not have acquired either the strong foundation in quantitative methods nor the disposition that many years later was captured by the slogan "Spartans Will." Wrigley, Sim, McQuitty and other colleagues in the Computer Institute for Social Science Research provided the mentoring that got me started. They generously gave me time before it was at all evident that I might become a decent scholar. I hope that one way or another I have been able to help the generation after me to do some good and to have exciting and productive careers.



# Parenting Styles and Child Language Development: Comparing U.S. and Chile

Rachel Nelson and Simone Alhagri | Department of Communication

## Abstract

Due to their importance for cognition and communication, language skills are some of the most important skills you need throughout life (Homer & Tamis-LeMonda, 2013). In early childhood, parents are the biggest determinants of a child's language development (Bee et. al., 1982). We hypothesized that children with Authoritative parents (parents who enforces rules while allowing self-expression) would have stronger receptive and expressive skills compared to children with Authoritarian parents (parents who provide strict discipline without allowing self-expression) (Baumrind, 1971). Furthermore, we hypothesized that these results would be similar across two cultural contexts: the United States and Chile. 174 parent-infant dyads participated in the study. Linear regression models were used to test whether the parenting style at 12 months predicted children's language scores at 30 months, controlling for culture, family socioeconomic status, and children's language scores at 12 months. Results revealed that parenting style has significant associations with receptive and expressive language development in both countries.

## Introduction

A study by Landry et. al. (2002) showed that the quality of language skills a child has at the end of toddlerhood (three years of age) can be used to predict the quality of language development for later years. However, language skills at four years old did not show the same effect; they did not predict later language development skills (Landry et al., 2002). More research is needed on the particular aspects of parenting that promote children's early language skills in order to help parents provide optimal support for their children.

Information on how parenting style affects language development is needed because it may help parents to understand how important their job is and how what they do at early stages of development will affect the future. Language development can also impact companies and the future economy because children will eventually enter the workforce as adults; therefore, it is important that they have enough knowledge and skills to successfully enter and stay in the workforce. Since parents make up a big percentage of the workforce and have to balance work life with family life, easing the stress of work-family life can be beneficial for companies. If parents are less stressed at work, they have more energy to devote to spending time with their children and to being more involved in their lives. Being more involved in a child's life leads to youth who have a greater psychological autonomy and school achievement (Dornbusch et al., 1991), which predicts how well they perform in college (Williford, 2009) and their subsequent preparation to be part of a productive workforce. This shows that both parenting and the workforce have huge effects on the development and academic success of a child, and that having a more parent-oriented workplace now can lead to having a highly qualified workforce in the future.

As mentioned earlier, children will eventually become adults and enter the workforce. In order for them, as well as the economy, to be successful, good communication skills are required. This is especially true since more emphasis is being placed on developing interdisciplinary teamwork in the workplace. Future workers will need to know how to communicate in a way that is easy for everybody to comprehend because similar communication patterns help to build trust between people of different disciplines (Bracken & Oughten, 2006). Therefore, it is important that parents know which parenting strategies will produce the best results for their child's language development.

**TABLE 1.** Sample demographic characteristics for the U.S. and Chile.

	Percent of Sample or Mean (SD)	
	U.S.	Chile
Girls	53.5%	42.7%
First or only child	54.9%	60.2%
Child age in months at Wave 1	12.0 (1.34)	12.2 (1.46)
Hours/week in child care	38.32 (9.99)	38.69 (7.30)
Mothers as primary caregiver	88.7%	81.6%
Mothers' age (years)	31.96 (5.48)	27.46 (6.82)
Fathers' age (years)	33.87 (6.61)	30.50 (8.26)
Mothers' educational level	6.07 (1.07)	4.52 (1.36)
Fathers' educational level	5.56 (1.16)	4.23 (1.65)
Mothers' occupational level	4.17 (0.92)	3.76 (1.12)
Fathers' occupational level	4.03 (1.06)	3.51 (1.32)

One of the most common and useful ways to describe parenting style in the U.S. has been to use Baumrind's (1971) classification of Authoritative, Authoritarian, and Permissive parenting. These parenting styles have been studied with respect to their relationship to children's social-emotional development and academic achievement, but not specifically to children's language development. In this study, we are interested in two of Baumrind's styles: Authoritative and Authoritarian. Authoritarian parenting style means that parents are very strict and only allow the child to have a very limited sense of freedom and self-expression (Baumrind, 1971). These parents make almost all of the decisions for the child for a majority of their life at home and rarely allow the child to learn from experience. Authoritative parenting style means that the parents set rules while still allowing the child to have some freedom and self-expression. The family still maintains balance by allowing structured freedom for the child; as a result, everybody feels respected and nobody feels belittled (Baumrind, 1971). These parenting styles might have a relationship with receptive and expressive language development by influencing the level of freedom that the child is given to express him or herself. For example, the Authoritarian style might not allow the child to learn from experience, so the child only has to exert minimal effort into understanding concepts and ideas and learning how to express them. On the other hand, the Authoritative style might encourage children to exert effort into understanding and learning language rules, and allow children the freedom to express their own

ideas. Having the child actively participate in learning helps expand their vocabulary (Tamis-LeMonda & Rodriguez, 2008). Besides freedom, other parenting aspects that are associated with the rate of language development are maternal sensitivity and negative-intrusive parenting tendencies (Pungello et al., 2009), which are also related to Authoritative and Authoritarian styles respectively.

However, it is important to understand that every culture has different customs, and the particular parenting practices that produce the best results in one culture might not produce the best results in another culture. Studies have shown that culture has an effect on parenting (Julian, McKenry, & McKelvey, 1994); thus, studying multiple cultures may help us observe the effect of culture and find the best way to parent children according to the specific culture or discover whether certain parenting styles are effective across multiple cultural contexts. Another important factor that has a link to both parenting and children's language development is socioeconomic status (SES) because it helps predict the quality of parenting and amount of language the child will hear (Hart & Risley, 1992); it also helps predict the rate of language development (Pungello et al., 2009). In fact, any study of the effects of parenting on children's language must also take into account the family's SES status.

## Current Study

The current study addresses the following questions:

**TABLE 2.** Results for the fitted regression models for the effects of culture and parenting style on toddlers' language development (\*=  $p < 0.05$ ; \*\*=  $p < 0.01$ ; \*\*\*=  $p < 0.001$ ).

Predictors	Receptive Language	Expressive Language
Intercept	11.07*** (0.50)	10.89*** (0.55)
Wave 1 Language Scores (Z-score)	0.44~ (0.25)	0.28 (0.31)
Family Socioeconomic Status (Z-score)	0.75* (0.33)	0.57 (0.37)
Culture (US = 0, Chile = 1)	-0.31 (0.63)	-2.62*** (0.69)
Authoritarian (+) vs. Authoritative (-) Parenting	1.49* (0.66)	1.92** (0.71)
Model Fit		
R Square	0.24	0.38
F	8.46***	17.10***

1) Is parenting style associated with early language development? 2) If parenting style is associated with language development, will the Authoritative parenting style predict better outcomes than the Authoritarian parenting style in the U.S. and Chile?

## Methods

### Sample

The sample was 174 parent-infant dyads, with 103 parent-infant dyads from Chile and 71 from the U.S. The children (52% boys) were around 12 months (age range = 10-15 months) when the study began, and around 30 months when it ended. The adult sample (parents and other primary caregivers) included both men and women, though females were predominant. Education level ranged from elementary/middle school incomplete (level 1) to post-graduate degree completion (level 7); occupation level ranged from occasional and informal jobs (level 1) to high-level executive or owner of a mid-size to large company (level 6). There was variation in parents' ages, occupations, and levels of education across the U.S. and Chile, indicating that it was necessary to control for SES in our analyses (see Table 1 for more information on the U.S. and Chilean samples).

### Procedures

The initial cross-cultural, longitudinal study on which this project is based started in 2010, and the goal was to learn about the development of labeling, expression, and comprehension of emotions in children during toddlerhood within two cultures: those children living in one urban area of one Midwestern state, and those in one urban area in central Chile. The recruitment process began with enlisting participation from various child care centers in each urban area. After participation from the various schools was established, flyers were distributed throughout the classrooms of the children of appropriate ages, and sent home with families. Families were informed about the nature of the study and provided informed consent before their participation began.

All of the data were collected either at the child's home or child care center from both the parent and the child's primary caregiver at child care. Children and parents participated in four waves of data collection when children were approximately 12, 18, 24, and 30 months old; children and their childcare providers participated at 12 and 30 months old. Only data from the parents and children are used in the

current study, and only from waves 1 (12 months) and 4 (30 months).

Before the first and last waves of data collection, parents were sent surveys about their child's development to complete prior to the visit. Each visit with parents and children started with a five-minute free play (using a set of toys provided by the research team) between the child and parent, which was video-recorded for later coding. Afterward, several additional tasks, focused on either the child or the parent and child together, were used to assess the children's emotional skills and how they expressed emotions. Finally, the language assessment was conducted at the end of the visit. If it could not be completed with the parent because the child was tired or had lost focus, it was completed during the visit with the child and his or her caregiver at child care.

## Measures

**Demographics.** At the beginning of the study, a document was given to the families, asking them to list each parent's age, ethnicity, dominant language, occupation, and education level, as well as family composition, and details about the child's health history. Parents' education levels ranged from less than high school to more than college, and the parents' ages ranged from early 20's to late 60's. SES for each family was calculated based on a combination of the highest level of education and highest occupation status in each family. The SES ranged from lower class to upper-middle class; however, the average differed by country. According to the World Bank, Chile has a lower economic status than the U.S., with their gross domestic product at \$240 billion as of 2015, while the U.S. was \$18 trillion in the same year (in US dollars); thus, the meaning of SES may be different in each country. We accounted for family-level differences in SES by controlling for it in our regression models (see Table 2).

**Child Language.** Data on the infant's language scores was collected using the Bayley Scales of Infant Development (Bayley, 2006) at 12 months of age (Wave 1) and 30 months of age (Wave 4). This is a test given to children to measure their receptive and expressive language skills and how they progress over time. The Bayley scale includes multiple tests that are administered and scored by research-

**TABLE 3.** Items chosen from the Sensitivity Scale to reflect Authoritarian vs. Authoritative parenting styles during the interaction.

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Prioritizes the child's interest rather than their own interest
Gives the child time to take initiative
Promotes and allows for communication
Allows for turn-taking with the child
Verbalizes the desires of the child in an appropriate way
Proposes activities that attempt a shared type of play
Play behaviors are interesting and change in an appropriate way
Verbal language is always positive and encouraging for the child during play, never teases or criticizes the child's behavior
Responds in an appropriate way to the child's signals

---

ers in order to provide an accurate presentation of the multiple areas of development, including social and emotional skills, expressive language, receptive language, cognitive skills, and motor skills. The scores are determined by how many questions the child answers correctly or how many tasks the child completes correctly. The two subscales reported in the current study were the expressive and receptive language scales.

**Expressive Language.** This subtest measures the child's ability to express ideas and intentions, name objects, label pictures of increasingly complex ideas, and ultimately the complexity of their spoken sentences. This test focuses on the words and gestures that the child produces.

**Receptive Language.** This subtest measures the child's ability to identify pictures and objects by spoken labels, and to understand pronouns, verb tenses, and prepositions when spoken to them. This test focuses on the child's understanding of the words, pictures, and actions that are being spoken to the child by the researchers.

The Bayley was chosen because it was shown to be reliable and valid both in the U.S. (Albers & Adam,



2007) and in other countries so as long as the pictures were changed to represent culturally recognizable objects (Cromwell et al., 2014; Hanlon et al., 2016). This includes countries with lower economic status than the U.S. (Biasini et al., 2015; Hanlon et al., 2016). In the pilot phase of the current study, an adapted version of the Bayley language scales was tested in Chile and found to be reliable.

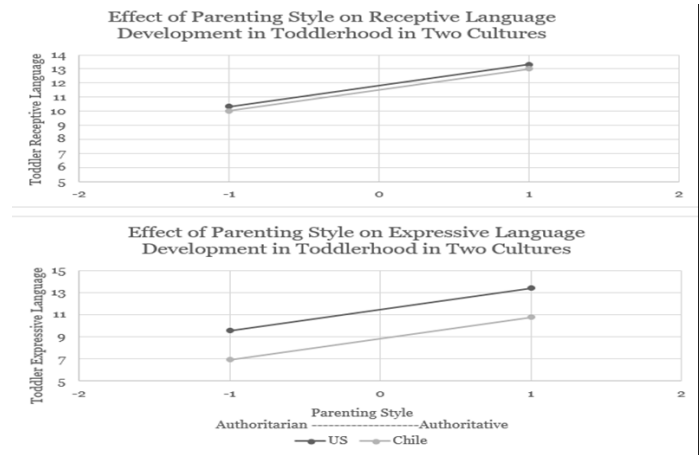
**Parenting style.** During Wave 1, the parent-child dyads were video recorded for five minutes while they played together with toys provided by the researchers (cars, dolls with bottle and blanket, puzzles, blocks, animal figures, rattles); meanwhile, the researchers stood out of the way in order for play to feel as natural as possible for both the parent and the child. The parents were told to play with the child as they normally would and to act like the researchers were not there with them.

Each video was analyzed and the parents were rated using multiple items from the Sensitivity Scale, which was created for this study as a collaboration between the Chilean and US members of the research team. The original scoring system is a three-point system with scores of 1 indicating less optimal parenting behaviors (e.g., Authoritarian) and scores of 3 indicating more optimal parenting behaviors (e.g., Authoritative). The original Sensitivity Scale included 19 items; however, for the purposes of this study we selected only items that we considered to reflect the distinction between Authoritative and Authoritarian behaviors (see Table 3). Anything on the Sensitivity Scale that could not be used to distinguish between the Authoritative and Authoritarian parenting styles was not used for the study.

Items from the Parenting Subscale were averaged together to create a single composite score. While the original scoring system was 1-3, for the purpose of creating a meaningful standard score, we created a z-score which has a mean of 0 (representing a parenting style that is neither very Authoritative nor very Authoritarian) and standard deviations of 1. Thus, a score of -1 indicates an Authoritarian parenting style, and a score of +1 indicates an Authoritative parenting style.

## Analysis and Results

Linear regression models were used to test the



**FIGURE 1.** Effects of parenting style scores on toddler's receptive language scores (top) and expressive language scores (bottom) at 30 months of age for children in the U.S. and Chile.

hypothesis that children whose parents were more Authoritative when they were infants would have better receptive and expressive language scores at 30 months as compared to children whose parents were more Authoritarian. We controlled for language scores at 12 months in order to interpret the dependent variable as an indicator of change during the toddler period. We also included country (U.S. or Chile) and SES. Results of the fitted regression models for receptive and expressive language are in Table 2.

Our hypothesis was supported. Parenting style did have an effect on both receptive (Figure 1, top) and expressive (Figure 1, bottom) language development, with an effect size of 0.35 for receptive language and 0.43 for expressive, across the U.S. and Chile. Further, children whose parents had a more Authoritative style at 12 months old had higher language scores on the Bayley Language Scales at 30 months.

Results showed a significant relationship between parenting style and early language development across both receptive and expressive language. Further, there is an effect of SES on children's receptive language. Culture remained a strong predictor of expressive language development even after accounting for SES, while SES was a stronger predictor of receptive language. When accounting for both culture and SES, parenting style was still a significant predictor of language development for both receptive and expressive language (see Figure 1).

## Discussion

Our hypothesis was supported. Parenting style is associated with children's early receptive and expressive language development. Children of Authoritative parents have higher language scores in a sample that included families from both the U.S. and Chile (Figure 1). This indicates that the quality of Authoritative and Authoritarian parenting and its associations with child development are not limited to the North American culture where the research on these parenting styles began. This also shows that allowing children to learn and explore on their own while providing reasonable boundaries is beneficial for their language development.

It is worth noting that SES is a strong predictor of child language development, but parenting style had a stronger effect in our model, possibly due to parents having a direct impact on the child. However, SES had a more distal impact, which occurs largely through parent-child interactions. It is believed that finances and the amount of resources available to the parent determine the amount of resources available to the child (Cerny, 2009). As a result, if resources and finances are limited, parents have to be stricter and have more control in order for everything to run as smoothly as possible (Conger et al., 1994). Having access to more resources increases the chance of the child receiving a higher quality education due to having more teachers and instructors that meet or exceed professional guidelines and recommendations, and therefore increasing the potential of higher development (Burchinal et al., 2000). In our study, SES also explained the difference in receptive language between the U.S. and Chilean samples, although this is not the case with expressive language where U.S. children scored higher, even after adding SES to the controls. It is important to note that this is not due to parenting differences, but societal differences.

Initially, we had tested whether parenting style at 12 months would associate with language as early as 12 months. However, it was not surprising to discover that parenting styles were significant for language at 30 months (Wave 4), but not significant at 12 months (Wave 1). Our belief is that this is likely because it takes time for parenting to show its effects on language development.

## Limitations

One limitation of the study was the amount of variance due to using data from a volunteer response sample. Further, our analyses only included culture, SES, and parenting. There was very little variety in the U.S. participants in SES, as most of the adult participants were middle-class and mothers. This provided little chance to study wider variations in parenting in the context of different financial situations, or to contrast the effects of mothers' and fathers' parenting styles. Though our sample was big enough to test these hypotheses by combining across the two countries, it was too small to test our hypotheses in each country by itself. Future studies should examine these questions in separate cultures on their own to determine whether the relationships between parenting and child outcomes work the same way across cultures.

## Conclusions

It is crucial to understand what strategies and techniques work best for parenting children in each society. While there is no single technique that is guaranteed to work best for every child, some have been shown to be more effective and beneficial than others on average. This study contributes to the body of knowledge that shows just how critical parenting is for influencing early language skills, and demonstrates that allowing children to have more freedom and autonomy is associated with better language outcomes. These early communication skills have a strong impact on later academic, personal, and professional success; consequently, parenting which supports children's expression early in life will likely have a long-term impact on their future.

## Acknowledgements

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# Highlights of Undergraduate Research

Campbell, Erin, "Participatory museums: The user experience of creative agents," *Special Interest Group on the Design of Communication*, September 23 - 24, 2016.

Drotos, Audrey, "Perceived grouping in auditory rhythms," *Rhythm Production and Perception Workshop*, July 3 - 5, 2017.

Grasser, Lana, Gupta, Mohun and Kabbash, Michel, "Attentional connectivity networks and their implication in reading and memory," *National Conference on Undergraduate Research (NCUR)*, April 5 - 8, 2017.

Hughes, Kendall and Smith, Karah, "Pop culture's influence on the stories we hear in music," *National Conference on Undergraduate Research (NCUR)*, April 5 - 8, 2017.

Ireland, Zach, "Slow Joe and fast Mary: statistical learning of talker rate influences and word perception," *30th Annual CUNY Conference on Human Sentence Processing*, March 30 - April 1, 2017.

Kierczynski, Katie, "Terrestrial vines on submerged woody debris influence macroinvertebrate community structure," *Society for Freshwater Science (SFS) Annual Meeting*, June 4 - 8, 2017.

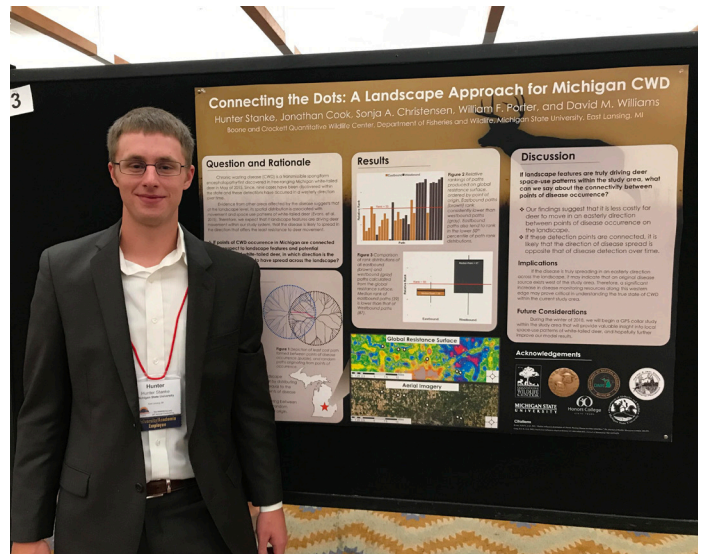
Kiple, Chloe, "Flint med," *American Educational Research Association Conference*, April 27 - May 1, 2017.

Ladson, Brittany, "In vivo analysis of aerobic terminal reductases in *Shewanella Oneidensis*," *National Conference on Undergraduate Research (NCUR)*, April 5 - 8, 2017.

Morrow, Matthew, "Total synthesis of complex molecules," *ACS National Meeting*, August 21-25, 2016.

Roehler, Ryan, "Reflections on my journey with the My Brother's and Sister's Keeper program: Doing authentic civic engagement," *National Council for Black Studies 41st Annual Conference*, March 8 - 12, 2017.

Sadler, Zachary, "Differences in material properties of thigh and gluteal soft tissue between males and females," *Summer Biomechanics, Bioengineering, Biotransport Conference (SB<sup>3</sup>C) 2017*, June 21 - 24, 2017.



Hunter Stanke poses for a photo next to his poster, "Connecting the Dots: A Landscape Approach for Michigan CWD." His poster received the best poster award. **Courtesy Photo**

Salatino, Joseph, "Plasticity in the excitability of neurons surrounding implanted neuroprostheses," *Society for Neuroscience*, November 2016.

Stanke, Hunter, "Investigating the effects of landscape connectivity on the occurrence of chronic wasting disease in Michigan," *24th National Meeting of the Wildlife Society in Albuquerque*, September 26, 2017.

Teneqexhi, Vicktoria, "Culture and training in music-narrative cognition," *National Conference on Undergraduate Research (NCUR)*, April 5 - 8, 2017.

Turner, Micah, "Analyzing safe bicycling practices on university campuses," *DC Health Communication Conference*, April 28-29, 2017.

# About the Contributors

**Simone Alhagri** is a Detroit native and one of the author's of "Parenting Influence On Child Lan-



guage Development: Comparing U.S. and Chile." She was a research assistant for three professors during her time at Michigan State University. One of her projects included working with an international research team in Chile to pose innovative questions about infant and child develop-

ment. Alhagri and her collaborator, Rachel Nelson, presented this work at the University Undergraduate Reseach & Arts Forum. During her time at MSU, she enjoyed being a teaching assistant, vice president of programming for the Undergraduate Communication Association, and attending major sporting events. She recently graduated with honors in communication and minors in public health and epidemiology, health promotion, and bioethics. Currently, she is a global health intern at Henry Ford Hospital in Detroit, Michigan. Simone plans on continuing her academic success in graduate school by pursuing a master's of public health in the fall of 2018.

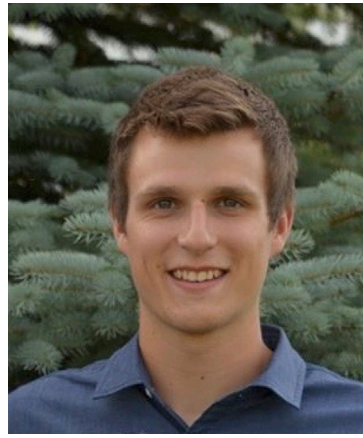
**Jean Klochko Bull** is a Honors College



senior majoring in mechanical engineering in the College of Engineering, and Spanish in the College of Arts & Letters. She volunteered in the Cardiovascular and Tissue Mechanics Laboratory under Professor Seugnik Baek, and assisted in studying pulmonary arterial hypertension. Upon

graduation, Bull plans to pursue a job in the field of biomechanical engineering.

**Nathan McLean** is a senior at Michigan State University earning a bachelor's degree in mechani-



cal engineering with a concentration in bio-medical engineering. He is currently working in Professor Seugnik Baek's Cardiovascular and Tissue Mechanics Laboratory as an undergraduate researcher. His research focuses on the relation between arterial stiffness and

hemodynamics of pulmonary hypertension patients, including the effects of wall shear stress, velocity, and pressure on arterial resistance, compliance, and vascular remodeling. He enjoys playing and watching sports, woodworking, and chess.

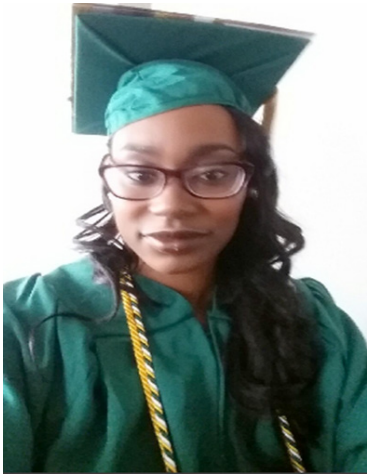
**Emily Oja** is an Honors College graduate who completed a bachelor's degree in fisheries and wild-



life from the College of Agriculture and Natural Resources in May 2016. While attending MSU, she worked with Catherine Lindell on projects involving mitigation of bird damage to fruit crops in Michigan. As an undergraduate, she was a member of the Spartan Marching Band and volunteered in Dr. Jean Tsao's lab

working on tick and Lyme disease projects. During the summers, she has held field jobs working with bald eagles, song birds, and bats. She is currently pursuing a master's degree in wildlife biology at the University of Montana, researching the effects of prescribed burning and mechanical thinning of forests on bird and insect pollinator communities.

**Rachel Nelson** graduated from Michigan State University in December 2017 with bachelor's degrees in neuroscience and psychology and a minor in philosophy. She was a member of the Charles Drew Science Scholars and the American Psychological Association.



She was a research assistant to Claire Vallotton in the MSU Department of Human Development and Family Studies (HDFS), researching the relationship between parenting, developmental

psycholinguistics, and early childhood social development. She was also a research assistant to Professor Michael O'Rourke in the Department of Philosophy researching the relationship between scientific objectivity and motivation. In 2015, Nelson interned at the Judson Center-Oakland Campus where she was a mentor to teenagers with autism, and in 2016, interned at the Karmanos Cancer Institute where she partici-

pated in research relating to health disparities between ethnicities. She plans on furthering her education over the next few years, and also plans to combine all of her experiences by conducting research focusing on racial health disparities in the field of mental health.

**Brigid Kennedy** is a senior studying comparative cultures and politics in the James Madison College, with a specialization in European studies and a minor in Spanish.



Her research interests include ethnic conflict as portrayed in national literature and visual culture. She is a member of the human rights working group researching bail reform for the Roosevelt Institute and currently serves as the

campus editor for *The State News*. She plans to pursue graduate study in comparative literature.



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