Mammalian dive response lab report

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Introduction

The mammalian dive response, or dive bradycardia, was first portrayed by Edmund Goodwyn in 1786 (Godek and Freeman, 2022). The response involves physiological changes during a dive that help mammals conserve oxygen. It consists of paused respiration and lowered heart rate based on previous studies using mammals (Panneton and Gan, 2020). The mechanism of this response starts with the sensory information from the nose, once the face is submerged under water, which is sent to the brainstem. The brainstem then sends the signals to specific organs using a parasympathetic nerve, the vagus nerve. The activation of the parasympathetic nervous system causes a decreased heart rate, and blood flow to be directed towards more vital organs (Godek and Freeman, 2022).

Many studies testing the dive bradycardia in mammals have been done throughout the last few decades. Several findings show that the temperature of the water impacts the strength of the diving response. One study found that immersion in cold water showed the lowest heart rate, compared to warm water, and breath holding without immersion in water (Kawakami et al., 1967). In addition, another study found that air temperature before the dive also plays a role. Immersion in cold water following exposure to high surrounding temperatures resulted in the most significant bradycardia (Schagatay and Holm, 1996). Interestingly, a third study showed that cold water immersion not only caused bradycardia, but also led to a decrease in tissue oxygenation and lower muscle soreness during exercise post-dive (Yeung et al., 2016).

Previous data consistently facilitated the idea that lower water temperature leads to lower heart rate during immersion. In our experiments, we wanted to test the effects of breath holding; breath holding in cold water and breath holding in warm water, using college-aged adults. Based on past literature, we hypothesize that breath-holding in cold water will result in the lowest heart rate compared to the other experimental conditions.

Methods

We used Neur 301X – Neuroscience: Neuron to Brain Lab Spring 2023 Lab 6 – Mammalian Dive Response Manual for all procedures (Schwalbe, 2023).

PowerLab and LabChart7 setup

Firstly, we connected the Finger Pulse Transducer to Input 1 in PowerLab and the Respiratory Belt Transducer to Input 2 in PowerLab. We connected the thermocouple to a T-pod, which was connected to Input 3 in PowerLab. Next, we set up LabChart7 settings according to the manual. Channel 1 was recording input from the Pulse Transducer (mV). Channel 2 was recording heart rate (BPM) from the finger pulse. Channel 3 was recording input from the Respiratory Belt Transducer (V). Channel 4 was recording respiratory rate (Hz) from the Respiratory Belt. Lastly, Channel 5 was recording the input from the thermocouple.

A volunteer from our group, Kotryna Andriuskeviciute, was the subject of this series of experiments. We attached the Finger Pulse Transducer to her middle finger and secured it using the Velcro strap. We attached the Respiratory Belt Transducer around her torso (lower rib cage area) and secured it with the Velcro strap. Kotryna was sitting down with her arm on the table around the level of her heart throughout the whole procedure. We then recorded around 30 seconds of Kotryna breathing normally and then auto scaled all of the channels to prepare for the experiments.

Baseline Data Collection

The volunteer rested for 4-5 minutes to ensure that her heart rate was settled. We then started LabChart measurements for about 1 minute to record her resting heart rate. Then, the volunteer held her breath for around 40 seconds while we recorded LabChart measurements of heart rate and respiratory rate for the first 15 seconds of her holding her breath and again for the last 15 seconds of her holding her breath. We also took the same recordings immediately as she took her first breath after the breath holding. We let her rest for around 2 minutes and then recorded the heart rate and respiratory rate using LabChart after recovery.

Cold-water Immersion

The volunteer rested for around 5 minutes to settle down her heart rate fully. We used a plastic bin which was already filled almost a third of the way with ice to fill it up with cold tap water. We used the thermocouple to record the temperature of the water. We used the baseline data as the cold dive control. The volunteer then fully submerged her face into the cold water for around 35 seconds as we recorded the heart rate and respiratory rate on LabChart for the first 15 seconds of the dive and again for the last 15 seconds of the dive. We recorded the LabChart data again, immediately after the volunteer reemerged from the water and took her first breath. After letting the volunteer rest for two minutes, we recorded the LabChart data again as she was breathing normally.

Warm-water Immersion

The volunteer rested for around 5 minutes to settle her heart rate down fully. We reused the plastic bin by dumping the cold, icy water into the sink and filled it with warm tap water. We used the thermocouple to record the temperature of the water. We recorded control data before the warm dive as the volunteer was holding her breath for 40 seconds without submerging her face in water (data recorded during the first 15 seconds of breath holding, last 15 seconds of breath holding, immediately as she took her first breath, and after a 2-minute recovery period). The volunteer then fully submerged her face into the warm water for around 35 seconds as we recorded the heart rate and respiratory rate on LabChart for the first 15 seconds of the dive and again, for the last 15 seconds of the dive. We recorded the LabChart data again, immediately after the volunteer reemerged from the water and took her first breath. After letting the volunteer rest for two minutes, we recorded the LabChart data again as she was breathing normally.

Data Analysis

We collected all of the LabChart data we collected and posted it on the shared Excel spreadsheet Dr. Schwalbe created. The spreadsheet contained data from groups across all three NEUR 301 lab sections. For data analysis, we used heart rate data from our volunteer (Kotryna) as well as data from two more volunteers taken from the shared spreadsheet (Group initials: MOC and MM). We calculated the mean and standard deviations of the three sets of data for all experimental conditions in Excel. We then used the means to make figures comparing the results (using the standard deviations for error bars).

Results

During the cold dive control, the mean heart rate of the three volunteers dropped from 84.96 BPM at rest to 77.83 BPM during the last 15 seconds of the breath holding. The cold dive data (water temperature: 4.2 degrees C) also showed a heart rate decrease with mean heart rate dropping from 82.67 BPM at rest to 55.35 BPM during the last 15 seconds of the dive (Fig. 1). The heart rate right after breath holding increased in both conditions (78.08 BPM in cold dive control and 56.87 BPM in cold dive condition). Compared to the percent difference from heart rate at rest, the mean heart rate decreased by 9% during the last 15 seconds of the cold dive control breath holding. In contrast, the mean heart rate decreased by 35% during the last 15 seconds of the cold dive (Fig. 2).

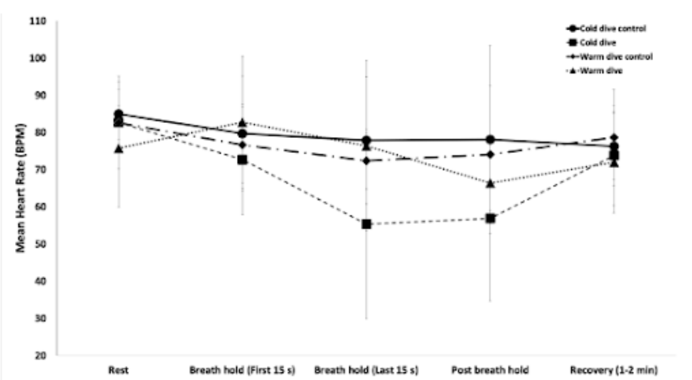
During the warm dive control, the mean heart rate went from 82.57

BPM at rest to 72.34 BPM during the last 15 seconds of the breath holding. During the warm water immersion (water temperature: 29.8 degrees C), the mean heart rate increased from 75.73 BPM at rest to 82.73 BPM during the first 15 seconds of the dive. It decreased to 76.39 BPM during the last 15 seconds of the dive and then to 66.35 BPM immediately after the dive (Fig. 1). Compared to the percent difference from heart rate at rest, the mean heart rate decreased by 13% during the last 15 seconds of the warm dive control breath holding. In contrast, the mean heart rate increased by 2% during the last 15 seconds of the warm dive (Fig. 2).

Discussion

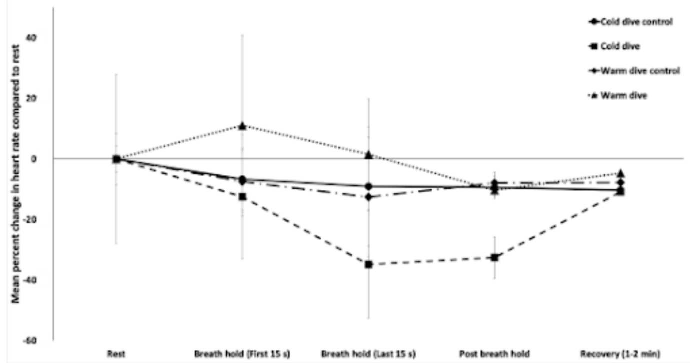
Studies testing the effects of water temperature on heart rate during diving bradycardia consistently found that immersion in cold temperature water elicited a lower heart rate when compared to immersion in warm water or breath holding without water immersion (Kawakami et al., 1967). Our data facilitates these findings and supports our hypothesis. The mean heart rate of three volunteers was lower during the dive in cold water (during the first and last 15 seconds of the dive) compared to the mean heart rate during the dive in warm water (Fig. 3). To further support this, the percent change of mean heart rate was -35% during the last 15 seconds of the cold dive and 2% during the last 15 seconds of the warm dive (Fig. 2). The warm dive data was not what we expected, since heart rate was higher during the warm water dive when compared to heart rate at rest. Looking back at the data, I noticed that the warm dive heart rate data for the volunteer from the MOC group did not match the warm dive heart data of the other two groups and the expected results. Their resting heart rate was 66.5 BPM, and the heart rate went up to 95.2 BPM during the first 15 seconds of the dive and down to 88.81 BPM during the last 15 seconds of the dive. Some experimental error was likely involved in those measurements, since the other two volunteers both showed a decreased heart rate during the warm water dive (Still not as low as the heart rate during the cold water dive). In addition, water temperatures most likely varied between the volunteers, which could have impacted the heart rates. In addition, since the experiments were run during different days, the air temperature in the room could have varied. According to Schagatay and Holm, that can impact the change in heart rate from “resting” to “during dive” (1996).

Despite us having a low sample size and some sources of error, the results still support the hypothesis that immersion in cold water leads to the largest decrease in heart rate in college aged adults. In the future, this procedure should be replicated with a larger sample, more replication for each volunteer, and more similar conditions (water and room temperature).



x-axis main label missing: Stages

Fig. 1. Excel plot comparing the mean heart rate (BPM) of 3 different volunteers (1 from our group, 1 from MOC, and 1 from MM). The heart rate was recorded and compared at five stages. The graph compares four different experimental conditions: cold dive control (heart rate at the five stages before the cold dive experiment), cold dive (heart rate at five stages with the volunteer holding breath with their face submerged in ice cold water - 4.2 degrees C), warm dive control (heart rate at the five stages before the warm dive experiment), and warm dive (heart rate at five stages with the volunteer holding breath with their face submerged in warm water - 29.8 degrees C).



x-axis main label: Stages

Fig. 2. Excel plot comparing the mean percent change in heart rate compared to rest (0 on the y-axis) of 3 different volunteers (1 from our group, 1 from MOC, and 1 from MM). The graph compares four different experimental conditions: cold dive control (heart rate at the five stages before the cold dive experiment), cold dive (heart rate at five stages with the volunteer holding breath with their face submerged in ice cold water - 4.2 degrees C), warm dive control (heart rate at the five stages before the warm dive experiment), and warm dive (heart rate at five stages with the volunteer holding breath with their face submerged in warm water - 29.8 degrees C).

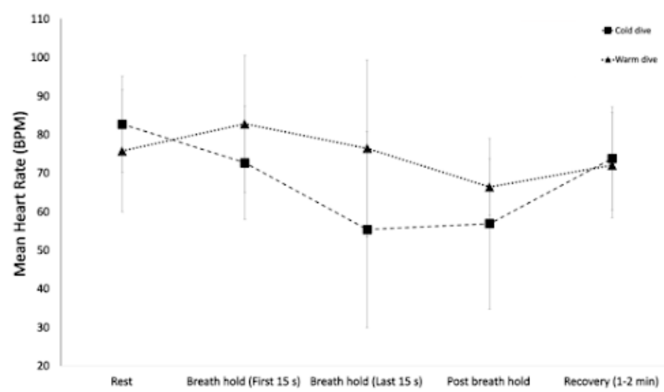


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Fig. 3. Excel plot comparing the mean heart rate (BPM) of 3 different volunteers (1 from our group, 1 from MOC, and 1 from MM). The heart rate was recorded and compared at five stages. The graph compares two experimental conditions: cold dive (heart rate at five stages with the volunteer holding breath with their face submerged in ice cold water - 4.2 degrees C), and warm dive (heart rate at five stages with the volunteer holding breath with their face submerged in warm water - 29.8 degrees C).

References

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