Designing a Device to Stimulate the Sternocleidomastoid to Validate the Usage of Neck EMG in EEG Data Cleaning

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Abstract

Electroencephalography (EEG) is a neuroimaging technique commonly used to understand the ways in which the human brain and body interact. Traditional EEG studies have taken place in stationary lab settings because of noise artifacts that are introduced during active behavior. When mobile EEG data is recorded, artifacts from various sources (e.g., line-noise, cable sway, muscle activity) mask the target brain data (Muthukumaraswamy, 2013; Somenidou, Nordin, Hairston, & Ferris, 2018). Eliminating artifactual noise remains a significant obstacle in mobile EEG studies, though advances in EEG hardware and signal processing methods have helped alleviate this problem. For example, independent component analysis (ICA) is a statistical method that has been successfully used to clean EEG data (Makeig, Jung, Lee, & Sejnowski, 1997). This project aims to validate the use of neck electromyograms (EMG) in ICA with the goal of removing these muscle artifacts from the EEG signals.

There is a need for a device that can engage and increase the signal amplitude of the sternocleidomastoid, a large neck muscle used for head rotation. The device will be used in tandem with electroencephalography and high density electromyography (HD EMG) to study neck muscle activity and ultimately improve EEG data cleaning. Design considerations regarding electrode interference, muscle engagement, mobility, stability, sizing, strength, resistance, cost, comfort, and safety all influenced the design process and final product. Several efficacy metrics were outlined in order to quantify the device’s success in meeting each of the design requirements and a protocol was developed in order to ensure proper usage of the device during data collection. A data collection with the final device and protocol will generate data that can be statistically analyzed and used to improve EEG ICA, thus validating the usage of neck EMG to improve EEG data cleaning.

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Introduction

The integration of technology into the human body promises to improve the capabilities and lifestyle of the physically disabled, actively deployed, and eventually, everyday people. Futuristic devices such as exoskeletons aim to give individuals superhuman capabilities, meanwhile high-tech bionic limbs seem to be the ideal option for providing mobility to the disabled. In order to engineer these devices, the existing properties of human motion, and the brain's role in this process, must first be understood.

Torres-Oviedo, Vasudevan, Malone, and Bastian (2011), among others, studied motor learning and locomotor adaptation while walking on a split belt treadmill. This research has significance in regards to neurophysiology and rehabilitation, in maximizing the brain's innate ability to adapt. With chronic stroke patients, for example, neuroimaging research has the potential to improve their weight-bearing and spatiotemporal symmetry (Reisman, Bastian, & Morton, 2009). Roemmich and Bastian (2018) highlight the importance of implementing the findings from motor neuroscience research into the development of clinical rehabilitation strategies. Among these research studies, non-invasive brain scanning techniques such as electroencephalograms (EEGs) have great potential for tapping into and understanding the brain's complex functions.

Improving EEG data processing is necessary to optimize the quantity and clarity of the data that can be drawn during experimentation. Noise artifacts, which come from a variety of sources, often interfere with the frequency signals that the brain emits. When using an EEG to monitor brain activity during a simple experimental task, the main sources of interference are alternating currents in the surrounding environment, ocular movements, and minute neck, face, and scalp muscle movements (Gebodh et al., 2019; Hu et al., 2015). These artifacts obscure the collected data, but signal processing is almost always used to make sense of the data

(Hu et al., 2015). One approach is called Blind Source Separation (BSS), which aims to filter out the noise artifacts based on second-order and higher-order statistics to isolate the brain's emitted frequencies (Chen et al., 2017).

One existing separation method is known as Independent Component Analysis (ICA). ICA is a statistics-based method of separating data out into different sources of activity. Some of these sources can then be identified based on their frequency spectra and rejected depending on their relevance. After component rejection, we would ideally be left with only the relevant, task-induced brain activity. ICA has been shown to be highly effective at separating out commonly-occurring artifacts through BSS in various studies (Chen et al., 2017; Delorme, Sejnowski, & Makeig, 2007; Fitzgibbon et al., 2016; Ma, Tao, Bayram, & Svetnik, 2012; Olbrich et al., 2011). If the source emits interfering frequencies with recognizable features, then, using the data from that source, algorithms can identify and remove its artifacts. After various algorithms filter through the collected EEG data, the processed data is a more accurate representation of the brain's frequency emissions.

ICA is an effective method at separating common noise artifacts in experiments that involve stationary tasks such as visual categorization (Delorme, Sejnowski, & Makeig, 2007). However, when studying the human brain in conjunction with body movement, other sources of artifacts arise, such as the physical movement of the EEG electrodes. Nordin, Hairston, and Ferris (2018) used a phantom head to test the efficacy of a new component separation technique. A phantom head was used instead of a human participant in order to avoid BSS. Instead, with the phantom head, the simulated brain activity could be known and controlled. The phantom head was placed atop a mechanical motion platform to induce physical movement of the electrodes and this activity's subsequent artifacts. Secondary electrodes pointing outwards on the phantom head were used to record only the movement artifacts from the surroundings. Using this data, the dual-electrode motion artifact cancellation technique was developed, which uses ICA and the environmental noise recorded to separate the EEG data into its various source components (Nordin, Hairston, & Ferris, 2018). Based on this approach, a dual-layer mobile EEG cap was designed to collect two full sets of data during locomotive EEG studies. An external layer of secondary electrodes is used to collect data solely on the surrounding environment during movement, while an internal layer of primary electrodes detects the overall activity coming from the moving head. The isolated data from the environment can be subtracted from the overall activity in order to eliminate movement artifacts. This electrode cap and separation technique are applicable to EEG studies involving physical movement, such as stepping over unexpected obstacles (Nordin, Hairston, & Ferris, 2019).

Another significant source for EEG artifacts is neck muscle activity. During locomotive EEG studies, neck muscles are involved with balance, posture, and head movement. The amplitude of neck muscle activity is larger than that of brain activity. Given the neck muscles' proximity to the cortical electrodes, any muscle activity in this region during an EEG recording will considerably contaminate the data.

Although there is research involving the identification of minute muscle movements in the face, scalp, and neck, more research regarding the exact muscles that are most activated during movement is still needed. Electromyography (EMG) is similar to electroencephalography in that it uses electrodes to measure electrical activity, but it is used for detecting muscle activity rather than brain activity. This study specifically focuses on using high density electromyography (HD EMG) to identify and remove neck muscle artifacts from EEG data.

The resulting data will provide information about the power spectrum associated with the usage of a large, superficial cervical muscle, the sternocleidomastoid (Fig. 1). There are two sternocleidomastoid muscles, one on each side of the neck, that are innervated by the spinal accessory nerve. They originate at the sternum and clavicle, and insert into the mastoid. Each muscle is used for rotating the head to the opposing side of the body as well as tilting the head to the same side of the body. The action of bringing the neck forward and downward requires the usage of both sternocleidomastoid muscles. A patient's

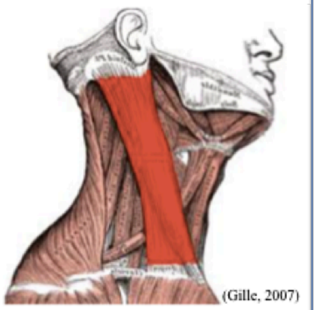
(Gille, 2007)

Figure 1. The sternocleidomastoid, highlighted in red.

sternocleidomastoid can be examined by providing a force against his/her cheek while he/she rotates his/her head in the opposite direction (Walker, Hall, & Hurst, 1990).

EEG neuroimaging will be recorded during the performance of a task both while the sternocleidomastoid is engaged and while it is at rest. The participant must complete a visual oddball task, which presents the participant with a repetitive visual stimulus followed by an oddball stimulus. This elicits a P300 wave as part of an event-related potential, an effect that is known as the oddball paradigm (Bernat, Shevrin, & Snodgrass, 2001). This task was chosen because it has been well-documented, so the results can be easily compared to existing studies.

Additionally, using an HD EMG array on the sternocleidomastoid when it is engaged, data on the emitted frequencies of this muscle during activity can be collected and analyzed using ICA. Following the principles of ICA, this data will be further analyzed by other lab members in order to improve source separation capabilities. If ICA can successfully isolate the excessive noise that is generated by the engaged sternocleidomastoid, then the same approach will likely be capable of isolating activity from less strenuous activities in real-world EEG studies. This research is valuable for making EEG technology easier to interpret in studies regarding human movement.

Methods

Design Requirements

The purpose of the device is to increase the sternocleidomastoid muscle activity for data collection in a research lab led by Dr. Daniel Ferris. A 50% maximum voluntary contraction (MVC) was chosen as the target exertion for the sternocleidomastoid. This contraction level was chosen so that the muscle activity will simulate excessively noisy data without tiring out or straining the participant's muscle over the course of multiple trials (Prasartwuth, Taylor, & Gandevia, 2005). The device will be used by a participant who must also wear an EEG electrode cap and two HD EMG electrode arrays. In an interview with Dr. Ferris, several design requirements were listed (Ferris, 2019; Table 1). These requirements drove the innovation process and made up the basis of the product development. The efficacy metrics are also listed for each requirement, indicating how one can quantify the success of the final design (Table 1).

Table 1.

List of Dr. Ferris' Design Requirements and Respective Efficacy Metrics

Design Requirements	Efficacy Metrics
I. Electrode interference - must not interfere with the user's EEG electrode cap or HD EMG electrode arrays	No points of contact between the electrodes and the movable components of the device
II. Muscle engagement - must increase EMG muscle activity by engaging the muscle	Engages the sternocleidomastoid at 50% MVC
	Continuously engages the muscle during the head rotation
	Increases the amplitude of the HD EMG signals when compared to control data
III. Mobility - must have a movable component to provide a counteractive force against head rotation	The movable component can rotate up to 45º to both the left and right when the user turns his/her head
	The spring has a spring constant that is capable of storing energy from 50% MVC of the sternocleidomastoid
IV. Stability - must have a stationary portion to provide stability	The stationary component moves less than 2º when the user turns his/her head
V. Sizing - must fit on various individuals	Can fit individuals with neck diameters within the range of 4.0 inches to 6.5 inches
	Cannot restrict breathing or swallowing abilities
VI. Strength and Resistance - must be strong and resistant over time	Resistant to 50% MVC of the sternocleidomastoid
	Design and materials are resistant to virtual testing with Finite Element Analysis
	Lubrication only has to be applied once before each data collection to combat friction

I. Electrode Interference

One major design challenge was that the device could not interfere with the EEG electrode cap or the HD EMG arrays (Fig. 2). An EEG cap follows the hairline, extending from the frontal bone down to the occipital bone in the back of the skull. The EEG electrodes cannot have physical contact with the device, or else they will likely undergo excessive movement during experimentation.

The HD EMG arrays should also be avoided in order to minimize their movement. However, they are generally held onto the skin with an adhesive fabric, which reduces the amount of movement that will occur. For this reason, avoiding the EEG electrodes is more vital than avoiding the HD EMG arrays.

Figure 2. Participants must wear an EEG cap and HD EMG patches during data collection.

II. Muscle Engagement

To exert muscle force, the brain sends a synaptic current to a muscle, which recruits motor neurons in order of smallest to largest. A motor unit is the basic functional unit of the nervous system, so the more motor units that are firing, the greater the muscle's exerted force is (Christou, 2019). Muscle movements are easier to detect using an EMG when more force is exerted because the amplitude of the signal is higher, which also makes analyzing the frequencies easier (Ferris, 2019). Additionally, if ICA is found to be capable of cleaning excessively noisy data, we will be more confident that it can remove muscle artifacts during less strenuous movements. Thus, in order to ease the process of detecting and analyzing the muscle movements, the sternocleidomastoid should be exerting a sizeable amount of force.

III. Mobility

In order to still allow for the user to turn his/her head to the side, part of the device must be movable, capable of following the biological movement associated with head rotation.

IV. Stability

A portion of the design must be stationary in order to allow for the compression of the springs when the movable portion rotates. This will increase the stability of the overall design, which is necessary, given that the device must be able to be used repeatedly during data collection.

V. Sizing

In order to make the device usable for several different participants, the device must fit individuals with varying neck and jaw dimensions. Several considerations, including the average neck diameter of men and women (Polanski, 2016) were used to create a targeted neck diameter range of 4.0 inches to 6.5 inches. The device should accommodate participants with neck diameters that fall within this range.

There are some safety concerns regarding the design and usage of the device, given that it is meant to be used in the head and neck region. The device must not confine the neck to the point of choking the user. The user must be able to perform unrestricted, normal breathing and swallowing while wearing the device and performing the tasks. If these issues do occur, they must be resolvable by adjusting the device.

VI. Strength and Resistance

The purpose of the device is to introduce artifacts from sternocleidomastoid contraction without the addition of artifacts from physical, jerky body movements. To do this, the device must increase the amount of force that the sternocleidomastoid muscle exerts to turn the head. However, the muscle and head movements must still be relatively controlled, because ICA requires the frequencies from the sternocleidomastoid during engagement to be isolated. To make the frequencies and amplitudes from trial to trial more consistent, the muscle activation must be the same every time.

The design of the specific parts must be strong enough to resist repetitive usage during testing. To test how the materials can withstand certain forces, virtual Finite Element Analysis can be completed. The device must be able to withstand at least 50% MVC of the user's sternocleidomastoid.

Additional Considerations

The comfort of the wearer of the device is important, given that they will be subjected to extensive testing. Padding on the interior of the device is needed to reduce discomfort and improve the user experience. Padding can also be used to make the device fit a variety of participants, making the device more adaptable.

The cost and duration of the final print are not of high concern given that this process must only be completed once. However, it is preferable to keep 3D printing during the prototyping phase as cost-effective and time-effective as possible. This involves the selection of the print material, print quality, and percent and shape of the infill.

Results

The final design of the device was based off of the design requirements as well as other additional considerations. Following the development of the device, small scale testing was conducted to ensure that all design requirements were met. The component features and fabrication methods are detailed below.

Component Features

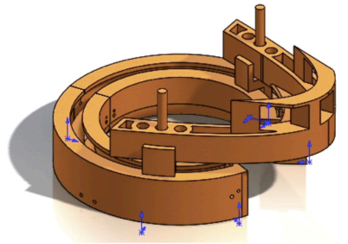

Figure 3. The final design, shown in SolidWorks.

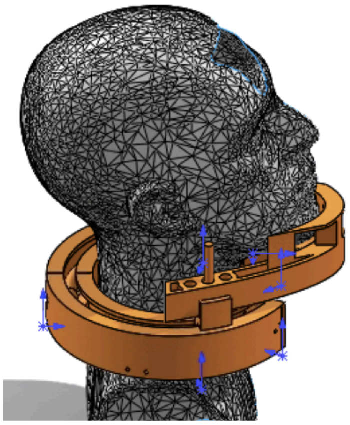

Figure 4. The final design surrounding a 3D model of a human head, shown in SolidWorks.

The final device is shown in Figure 3. Figure 4 shows the device on a 3D model of a human head. The device surrounds the neck and jaw and uses compression springs to store energy. As the user attempts to turn his/her head to the side, some of the force that the sternocleidomastoid exerts is used to successfully turn the user's head, while some is stored as elastic potential energy in the springs during deformation. As the springs resist deformation, they provide a counteractive force against the user's jaw movement, making head rotation more difficult.

The device contains four metal springs (two on each side of the neck) that surround a plastic cylindrical track. This track runs horizontally, following the circular shape of the neck. The springs, which lie on the track, can be compressed laterally to store energy. Placed between each pair of springs is a plastic plunger that also moves along the track (Fig. 5). This plunger is responsible for compressing the springs during head rotation. Each plunger extends upward to the under-ear region, where it connects to a large, plastic jaw support that surrounds the user's jaw (Fig. 6). Thus the jaw support is held up by two plastic plungers, one on each side, that can slide horizontally along the spring track surrounding the neck. This mechanism is meant to simulate the rotation of the head to one side or the other, with the springs storing energy as this takes place.

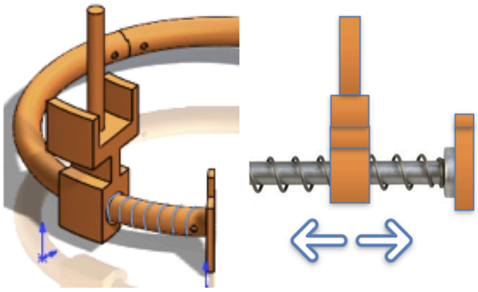

Figure 5. Inside the device, springs surround a cylindrical track. The springs are positioned so that they are stretched and compressed by the plungers as the user's jaw rotates.

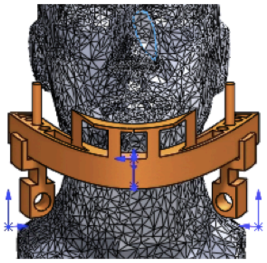

Figure 6. A jaw piece supports and moves with the jaw during head rotation. On each side, the jaw piece connects to a plunger.

The spring track is encased in an outer shell to isolate the spring movement as well as provide a stationary surface as the inner face (Fig. 7). This face will contact either the user's neck or interior padding if needed.

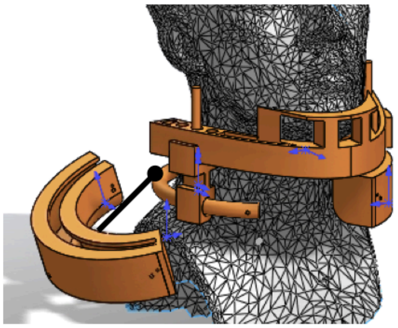

Figure 7. An exploded view of the device (indicated by the black arrow) shows that the inner spring track is contained within an outer shell. This isolates spring movement.

Fabrication

The device was designed using the CAD software SolidWorks 2019 and printed on a Markforged X7 3D printer. 3D printing was chosen as the fabrication method in order to allow for various printing materials and dimensions to be tested as needed. Two 50% scale prototypes were printed in order to allow for design improvements regarding how the parts fit together. These prototypes were printed in PLA+ with 25% square infill at standard print quality in order to reduce the cost and duration of the prototype printing process. For the final device, nGen co-polyester filament was used with a 50% square infill on a higher quality printer. This increases the strength of the material, resulting in an overall improvement in the stability of the device.

The steps that were taken to address each of the design requirements, as described in Table 1, are detailed below.

I. Electrode Interference

In order to prevent physical contact between the device and EEG and EMG electrodes, the device was partially modeled from a neck brace. Neck braces surround the neck and support the jaw, stretching from underneath the mandible to top of the collar bone. This design was appealing, because it relies on the shoulders and collar bone to provide support rather than attaching to the head. The relatively compact size of a neck brace makes this type of device versatile in terms of the type of experimentation for which it can be used. However, neck braces are typically used to restrict neck movement, and given that the device's purpose is to engage the sternocleidomastoid, an ordinary neck brace cannot be used.

II. Muscle Engagement

A 50% MVC was chosen as the target exertion for the sternocleidomastoid. This level of engagement eases the EMG collection process, as the amplitude of the frequencies is higher than if the muscle were not engaged for a sustained period of time. In order to continuously engage the user's sternocleidomastoid upon mandibular rotation, a continuous counteractive force must be applied against the user's jaw once his/her head begins to rotate. For this, springs were chosen as a way to store energy as the user's head is turned. Springs store elastic potential energy as they are compressed. Hooke's law states that the force (F) that is applied to a spring, equals the spring constant (k) times the change in length of the spring (x), or $F = kx$. The value of k essentially represents a spring's stiffness and depends on the type of material, dimensions, and shape of the spring. Given that the device will be used with the human neck muscles rather than for industrial purposes, the spring constant does not need to be heavy-duty. Rather, the spring constant must be such that the user can exert up to 50% of his/her MVC of the sternocleidomastoid upon turning his/her head to the side. With this level of stiffness, the user can produce an adequate amount of force from his/her sternocleidomastoid for EMG data collection. The optimal spring constant may vary from user to user based on individual strength, so the springs can be interchanged to make the device more adaptable.

III. Mobility

The jaw support piece and the plunger piece make up the movable component of the device. They can compress the springs during rotation. Several head rotations were observed in order to better understand the path that the mandible takes during rotation. The mandible was observed to follow a circular pattern around the spinal cord as an individual turns his/her head. Based on these observations, the device was designed to support the mandible from below and partially surround it on its sides. Due to the device's contact with this part of the jaw, it is able to rotate horizontally around the neck and spinal cord as a result of the user's mandibular rotation.

IV. Stability

The track on which the springs lie and the outer shell act as the stationary portion of the design. The design of these pieces was partially based off of a neck brace. Neck braces are meant to provide jaw support, making them a very stable design to model the device after.

To further promote stability, a commercial postural back brace that surrounds the underarms and shoulders was purchased (Fig. 9a). It was chosen for its compactness and adjustable straps

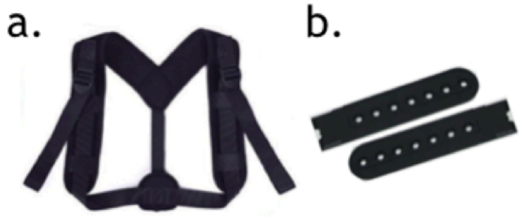

Figure 9. A) The outer shell of the device is anchored to a commercial back support product to promote stability. The straps are adjustable, making them suitable for all users. B) Plastic adjustable straps are used to fasten the device around the user's neck.

and will be attached to the device on both sides. This will anchor the device to a sturdy part of the user's body, which will reduce its movement.

V. Sizing

The necessary geometric dimensions to satisfy the specified range (Table 1) were calculated and implemented into the design. The average bigonial breadth (Leversha et al., 2016) was used to determine the width of the jaw support piece. Additionally, a 3D scanner was used to create a digital mesh of a human head. This mesh was then imported to SolidWorks, where several measurements were taken using the "Measure" feature. Using the "Assembly" feature, the dimensions of the mesh were compared with those of the device parts. Following this comparison, several scaling adjustments were made to the device parts.

The device's dimensions were made to be larger than the mesh in order to allow room for padding. The padding allows for a more individualized fit, especially in the jaw region, and also improves the overall comfort of the device for the user.

To allow for the adjustment of the parts surrounding the neck, mirrored pieces were printed for both the right side and left side neck pieces. These pieces are attached in the front and the back with a plastic strap with holes (Fig. 9b). Four holes were added to the front and back of the outer shell of the device. This feature that allows for the plastic strap to be fastened to the device at the proper alignment so that the inner circumference of the device can be varied from user to user.

A similar process was applied to the jaw piece. The path that the jaw follows upon rotation varies depending on the user's head and neck size. To accommodate for users will all jaw sizes, there are three sets of the holes in which the plungers can be inserted (Fig. 10). The set of holes that is closest to the chin is

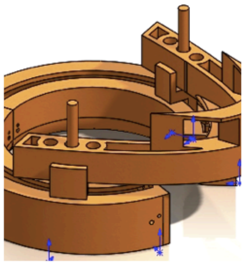

Figure 10. The jaw piece includes three sets of holes in which the plungers can fit. This is useful for participants with varying jaw dimensions and head rotations.

meant for users with a small jaw and path of rotation, whereas the furthest set is meant for users with a large jaw and path of rotation.

VI. Strength and Resistance

Given that the sternocleidomastoid is used to turn the head from side to side, this action must be performed repeatedly in order to achieve a multitude of consistent data points from the EMG. The device will be used in order to ensure that the head and neck movements are still controlled enough to be repeated with consistency various times for data collection.

Friction undoubtedly plays a key role in the movement of the individual parts of the device as they interact with one another. When the movable parts rotate, they rub against the stationary parts. In order to reduce this effect, the number of physical contact points between the movable parts and the stationary parts were kept to a minimum. The only contact surface between the stationary and movable parts occurs where the plunger slides along the spring track. The friction between these parts can be problematic in preventing the plunger from compressing the springs. Lubricant could be applied to the spring track to combat this issue. However, given the fact that there is little contact between these parts, the amount of lubricant needed is minimal and should have a relatively low reapplication requirements.

Discussion

Protocol Requirements

Using this device, EMG data can be collected over multiple trials and used for ICA. A brief protocol must be outlined in order to direct lab members on how to properly use the device during data recording. The purpose of the device is to ease the EMG data collection process and verify its application to EEG artifact cancellation techniques. The collected EMG data must be clear and isolated, as well as consistent across a multitude of trials. This allows for accurate data analysis in programs such as MATLAB and EEGLAB to take place following experimental data collection.

When determining the task that will be performed, it is important to consider that having the ability to compare the collected data to existing data is necessary to ensure the accuracy of the equipment. Thus, having the user perform a well-documented task to stimulate event-related brain activity is ideal. Additionally, standard EEG and EMG preparation and sampling techniques are adequate for the data collection, unless otherwise manipulated by the researcher.

Final Protocol

The participant will be in a sitting position with back support for the duration of the experiment. This will minimize any confounding EMG signals from off-target muscles that would come about if the participant were standing, as maintaining this position increases an individual's neck muscle usage (Jacobsen, 2019). Additionally, postural control and stability varies from one participant to the next (Moghadam et al., 2011). Recording EEG and EMG data in the sitting position will remove these extraneous variables.

A single-layer 128-electrode EEG cap will be placed on the participant's head and gelled with silver chloride gel. Two high density EMG electrode arrays will be placed parallel to the direction of the muscle fibers. The skin will be sterilized with ethanol and the ground electrode will be placed on the mastoid. A 1,000 Hz sampling rate will be used to record both the EEG and EMG data.

A visual oddball task was chosen as the task for the participant to complete in order to induce event-related activity in his/her brain. A 20 s video was used to present the visual oddball task to the participant. In the video, a white light stimulus is repeatedly flashed for 18 seconds. Then, a red light stimulus is suddenly flashed. This induces the oddball paradigm, causing momentary stimulation of the user's occipital lobe in response to the changing stimulus. This task was chosen because it has been well-documented to elicit a P300 component in the oddball paradigm, so the results can be easily compared to existing studies (Bernat, Shevrin, & Snodgrass, 2001).

In the stationary control condition, the participant wears the 128-electrode EEG cap and HD EMG arrays. The EEG picks up signals from the brain without any muscle interference, because the participant is not engaging their sternocleidomastoid. The participant will perform 50 trials of the 20 s visual oddball task. After the video is complete, the participant will rest for 20 s. This will be completed 5 times over the course of the 200 seconds. After this 200 s is complete, the participant will rest for 60 s with their head in the forward position. This process will be repeated 10 times for a total of 50 completed visual oddball tasks.

In the engagement condition, the same setup will then be performed. The only difference will be that the participant has to engage his/her sternocleidomastoid during the visual oddball task. Again, while wearing the 128-electrode EEG cap and HD EMG arrays, the participant will perform 50 trials of the 20 s visual oddball task. However, this task will be completed while the user turns his/her head to the right at 50% MVC. The participant must hold that position for the full 20 s of the video before returning to the resting position. The user will remain in the resting position for 20 s. This process will be completed 5 times over the course of the 200 seconds. After this 200 s is complete, the user will rest for 60 s with their head in the forward position. This process will be repeated 10 times, for a total of 50 completed visual oddball tasks during head rotation. In this condition, the EEG will pick up signals coming from both the brain and the sternocleidomastoid and the EMG will record the signals from only the sternocleidomastoid.

Applications

Further pilot testing is needed in order to determine if the duration of the trials is adequate to collect the appropriate amount of data. Once the protocol is confirmed and finalized, it can be implemented into a proper data collection in Dr. Ferris' lab. The stationary EEG visual oddball data and the engaged EEG visual oddball data can be compared to determine the effects of muscle interference on the EEG data. The isolated EMG data can then be used for EEG independent component analysis. Statistical analyses in MATLAB and EEGLAB can be performed to identify the source components that result from ICA. Using the EMG data that is collected in this experiment, certain statistics and patterns related to the sternocleidomastoid muscle activity can be used to more easily identify this source. Once it has been implemented, the data that this device and protocol will generate will have considerable applications in studies involving locomotive neuroimaging and other studies involving real-world EEG.

Conclusion

In conclusion, a device was designed in order to aid in the EEG and EMG data collection process. Design considerations regarding electrode interference, muscle engagement, mobility, stability, sizing, strength, resistance, cost, comfort, and safety all influenced the design process and final product. Several efficacy metrics were outlined in order to quantify the device's success in meeting each of the design requirements. Finally, a protocol was developed in order to ensure proper usage of the device during data collection. A data collection with the final device and protocol will generate data that can be statistically analyzed and used to improve EEG ICA, thus validating the usage of neck EMG to improve EEG data cleaning. This advancement will be useful for removing neck muscle artifacts from EEG data in future locomotive neuroimaging studies.

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