**Manuscript Reviewer Response**

**Editor #1:**

*Our senior BB editor told us earlier that it is required to have biosensor in the article.  See his earlier information provided to guest editors.*

*“****First of all is should be about “biosensors”.****It means the sensor only composed of physiological sensors are not considered as “biosensors” in this journal. There have been a long discussion, which we do not arrive in the conclusion, and our role is not provide any exceptional definition for biosensors in this special issue. However, as you saw in 2.innovative technologies, method and novel integrated devices will be considered which may compensate or even overwhelm the conventional biosensor principle based sensing, or as the integrated devices with the combination of “biosensors” and physiological sensors to provide useful information which cannot be acquired either of the principle, alone.”*

*I like your paper and moved it forward. I feel maybe during your revision, you can add some content on their defined ‘biosensors’ in the review?*

**Our Response:**

We thank the reviewer for the valuable comments and assessment of this review article. As this manuscript is written for submission to the Biosensors and Bioelectronics journal, a section has been added to comment on wearable sensor gloves that have integrated biosensors for biochemical sensing.

**Modification to the “Research-based WSGs” Section through the addition of a new section:**

**2.4.4. Examples of biosensors**

This section details a few examples of WSGs that utilize biosensors, and there are only a few projects that utilize these types of sensors, as this is a new application for biosensors. Although not specific to WSGs, a few broad literature reviews were conducted to highlight the existing biosensors in wearable devices (Min et al. 2021; Sonawane et al. 2017). A more focused literature review was conducted by Hubble and Wang in 2018 to highlight the existing wearable sensing gloves that utilize electrochemical sensors with a focus on forensic, security, and defense applications. (Hubble and Wang 2019). Mishra et al. built a WSG utilizing an organophosphorus hydrolase-based biosensor for on-site detection of organophosphorus chemical threats, such as nerve-agent compounds. They built a highly stretchable, printed electrode system as a wearable point-of-use screening tool for defense and food security applications (Mishra et al. 2017). Luo et al. built a WSG utilizing carbon nanotube-based amperometric biosensors to detect lactate. A combination of CNT and Ag/AgCl is required for highly sensitive detection and this device can be used for healthcare and defense applications (Luo et al. 2018). Barfidokht et al. created a WSG for rapid, on-site detection of fentanyl to decentralize opioid testing using a chemical sensor made from flexible, screen-printed carbon electrodes modified with a mixture of multiwalled carbon nanotubes and a room temperature ionic liquid, 4-(3-butyl-1-imidazolio)-1-butanesulfonate (Barfidokht et al. 2019). There is a lot of opportunity for biosensors to be further integrated with WSGs for future applications.

**Reviewer #1:**

*“General Comment: In this work, the authors have summarized recent progress of WSGs and SFDs for rehabilitation and prostheses. This review article has focused on the technologies used to develop a wearable sensing glove and a sensory feedback device. Besides, figures and tables in the review are impressive. However, the manuscript lacks sufficient details, and a few major concerns need to be addressed before it could be considered for publication.”*

**Our Response:**

We thank the reviewer for the valuable comments and assessment of this review article.

**Comment #1:**

*The abstract is confusing, please revise the abstract to make it more focused and complete.*

**Our Response:**

We have replaced the abstract to make it more focused and complete.

**Our Modification to the Manuscript:**

Wearable sensory gloves and sensory feedback devices that record and enhance the sensations of the hand are used in healthcare, prosthetics, robotics, and virtual reality. Recent technological advancements in soft actuators, flexible bioelectronics, and wireless data acquisition systems have enabled the development of ergonomic, lightweight, and low-cost wearable devices. This review article includes the most up-to-date materials, sensors, actuators, and system-packaging technologies to develop wearable sensing gloves and sensory feedback devices. Furthermore, this review contemplates the use of sensing gloves and sensory feedback devices together to advance their capabilities as assistive devices for people with prostheses and sensory impaired limbs. This review is divided in two sections: One detailing the technologies used to develop strain, pressure, and temperature sensors that are integrated with a multifunctional wearable sensing glove; and the other reviewing the devices and methods used for wearable sensory displays. We discuss the limitations of the current methods and technologies along with the future direction of the field. Overall, this paper presents an all-inclusive review of the technologies used to develop wearable sensing gloves and sensory feedback devices.

**Comment #2:**

*Please consult and cite relevant references to make a clear definition and explanation of WSG.*

**Our Response:**

We have added a sentence to the first paragraph in the introduction to address this discrepancy and provide more clarity.

**Modification to the first paragraph of the “Introduction” Section:**

A WSG is defined as a “glove-based system as a system composed of an array of sensors, electronics for data acquisition and processing, power supply, and a support for the sensors that can be worn on the user’s hand (dipietro et al. 2008).”

**Comment #3:**

*Figure 1 is beautiful and impressive, but there is no specific explanation or description of its meaning in the manuscript.*

**Our Response:**

We have modified the introduction to describe the relevance of figure #1.

**Modification to the fourth paragraph of the “Introduction” Section:**

Fig. 1 is an overview figure which précises the most relevant applications of these devices, the cutting-edge technologies used by these devices as described in this review, and it illustrates how a WSG and SFD could interact to provide comprehensive sensory information to a user.

**Comment #4:**

*How strain, pressure and temperature sensors are integrated with gloves? Please elaborate, it is important for WSGs and people are also concerned about this issue.*

**Our Response:**

We have added a few sentences to the first paragraph of the “Wearable sensor gloves (WSGs)” section to comment on how researchers integrate sensors into gloves.

**Modification to the first paragraph of the “Wearable sensor gloves (WSGs)” Section:**

These sensors are embedded into a glove using elastomers and epoxy adhesives (Hammond et al. 2014; O’Connor et al. 2017; Ota et al. 2016), threaded using sensor enabled fibers (Li et al. 2020b), and attached using thread and additional fabric (Hughes et al. 2020).

**Comment #5:**

*Since this review article focuses on the technology used to develop strain, pressure and temperature sensors, the working principle of the sensor, signal output form, etc. should all be explained in detail.*

**Our Response:**

For each sensor group, the working principle and signal output form are described in detail.

**Modification to the “Strain sensors made from silver nanowires” Section:**

Strain sensors made from silver nanowires exhibit a change in resistance as the strain on the sensor increases. This change in resistance can be measured using a wheatstone bridge amplifier.

**Modification to the “Strain sensors made from thread-based materials” Section:**

When strain is applied to the sensor, the sensor produces a voltage output corresponding to the strain applied. This voltage output can be amplified and sampled using an analog to digital converter.

**Modification to the “Strain sensors made from thread-based materials” Section:**

As the user bends their fingers, the resistance of the goniometer changes and this resistance change is converted to a voltage output using amplifiers

**Modification to the “Strain sensors made from thread-based materials” Section:**

As the strain increases, the resistance of the sensor increases.

**Modification to the “Strain sensors made from carbon-based materials” Section:**

Most carbon-based strain sensors made from carbon-based materials exhibit a resistance change when strain is applied.

**Modification to the “Strain sensors made from carbon-based materials” Section:**

Unlike the other carbon-based strain sensors mentioned in this section, this strain sensor exhibits a capacitance change when strain is applied to the sensor.

**Modification to the “Strain sensors made from OTS materials” Section:**

These OTS strain gauges listed below exhibit a resistance change when strain is applied to the sensor.

**Modification to the “Pressure sensors made from OTS materials” Section:**

When pressure is applied to the FSR sensor, the resistance of the sensor decreases.

**Modification to the “Capacitance-based pressure sensors” Section:**

The capacitance-based pressure sensors listed below produce a capacitance change when pressure is applied to the sensor. The pressure compresses the dielectric material between two parallel plates producing a capacitance change.

**Modification to the “Galinstan liquid-based pressure sensors” Section:**

The Galinstan liquid-based pressure sensors produces a resistance change when pressure is applied to the sensor. As pressure is applied to the sensor, the cross-sectional area of the channel that the Galinstan liquid is in decreases. As the cross section decreases, the resistance increases.

**Modification to the “Resistance, inductance, and transistor-based pressure sensors” Section:**

As pressure is applied to this pressure sensor, the resistance between the two conductors increases.

As pressure is applied to this pressure sensor, the inductance of the sensor increases.

As pressure is applied to this pressure sensor, the thickness of the air-dielectric layer decreases and causing an increase in current to flow through the transistor.

**Modification to the “Galinstan liquid metal temperature sensors” Section:**

As the temperature increases, the resistance of the sensor increases as well.

**Modification to the “Examples of temperature sensors” Section:**

These temperature sensors’ working principle is detailed such that as the temperature increases, the resistance of the sensor increases as well. This resistance change can be measured with various electronic circuits.

**Comment #6:**

*The various sensors listed in each section should be further classified, rather than simple temperature, strain and pressure sensors. This can help readers to read and understand better.*

**Our Response:**

We agree with the editor regarding this matter. We have added subsections to further clarify the examples provided.

**Modification to the Manuscript:**

**2.4.1.1. Strain sensors made from silver nano-wires**

**2.4.1.2. Strain sensors made from thread based material**

**2.4.1.3. Strain sensors made from carbon based materials**

**2.4.1.4. Strain sensors made from OTS materials**

**2.4.2.1. Pressure sensors made from OTS materials**

**2.4.2.2. Capacitance based pressure sensors**

**2.4.2.3. Galinstan liquid based pressure sensors**

**2.4.2.4. Resistance, inductance, and transistor based pressure sensors**

**2.4.3.1. Galinstan liquid metal temperature sensors**

**2.4.3.2. OTS temperature sensors**

**2.4.3.3. Ribbon-based temperature sensors**

**2.4.3.4. Fiber-based temperature sensors**

**Comment #7:**

*The author introduces recent progress of WSGs and SFDs. Please briefly introduce some examples of the combined application of wearable induction gloves and sensory feedback devices in the article, so as to make the manuscript more complete.*

**Our Response:**

There are few examples that combine wearable sensor gloves and sensory feedback devices. To clarify this point, a section has been added to highlight the projects that have integrated both.

**Modification to the last paragraph in the “Introduction” Section:**

The next section focuses on projects that combine WSGs and SFDs.

**Modification to the Manuscript with the addition of the “Combination of WSGs and SFDs” Section:**

As the previous sections covered WSGs and SFDs separately, this section focuses on projects that have integrated both devices. Simons et al. built a feedback system for upper limb robotic prostheses by combing a wearable sensor glove on a prosthetic limb with a feedback armband for the user. They placed pressure pads on the fingertips containing conductive liquid. A battery powered, electro-fluidic control unit transferred the pressure to an armband that was actuated by shape memory alloys to generate axial, radial, and circumferential forces (Simons et al. 2021). Baldi et al. built a feedback system for enhanced sensing and touching using a wearable sensing/actuation system glove. It uses inertial and magnetic sensors for hand tracking and transfers this movement to cutaneous devices for force feedback (Baldi et al. 2017). Schwedt et al. build a sensor glove to detect color with a feedback system for those with vision-loss or trouble perceiving color. There is an optical color sensor on the fingertip and a haptic feedback device integrated into an armband. The color data and finger selection is encoded using spatial and temporal parameters with positive color distinguishing results (Schwerdt et al. 2009). Bimbo et al. built a robotic teleoperation system using a WSG with a 6 axis IMU that was placed on a robotic hand. A wearable haptic armband with four vibrating motors is placed on the arm to transfer motion to the user who is controlling the robotic hand (Bimbo et al. 2017). Weber et al. constructed a sensor glove with an IMU and flex sensors for finger joint and hand motion sensing. This data was transferred to a vibrotactile feedback armband to wirelessly control a robotic arm for teleoperation (Weber et al. 2016). Rueckert et al. made a sensor glove with flex sensors to teleoperate a robotic hand. The robotic hand has tactile sensors on the fingertips and this touch information is transferred back to the user through vibration motors placed on the corresponding fingertip (Rueckert et al. 2015). Overall, these examples demonstrate the potential of combining WSGs and SFDs, however there are a lot more applications that have not been met.

**Modification to the “Conclusion” Section:**

There are few projects that demonstrate the combination of WSGs and SFDs, however, there are more applications and unmet problems that researchers have yet to tackle. As WSGs and SFDs advance separately, the combination of these two devices will benefit greatly.

**Comment #8:**

*When introducing the latest technology of WSGs and SFDs, it is necessary to provide your own opinions and perspective, rather than simply listing the literature.*

**Our Response:**

We agree with the reviewer that there is a lack of the author’s opinion and perspective. Therefore, we have added a few comments in the various sections to enhance the literature review.

**Modification to the “Applications of WSGs” Section:**

To have a long-term impact in this field, researchers need to focus on the problem that their WSG is trying to solve. If done successful, their research will have an impact beyond the academic community and hopefully their research will be commercially available to the public.

**Modification to the first paragraph of the “Research-based WSGs” Section:**

However, commercially available products have a better system design, data collection methods, and user interaction than academic wearable sensor gloves. If researchers improve the overall functionality of their devices, they can be used for more applications, clinical trials, and have a larger impact.

**Modification to the first paragraph of the “Do-It-Yourself WSGs” Section:**

These examples are provided to the readers in the hopes to inspire a different thought process and to discover novel applications.

**Modification to the “3.2 Pros and cons of each feedback mode” Section:**

Given the clear advantages of mechanotactile feedback, there is a need for smaller and more ergonomic mechanotactile actuators that could be more easily integrated into wearable devices.

**Modification to the “3.3 Limitations, challenges, and future work” Section:**

The development of a comprehensive sensory feedback device that can be incorporated into the daily lives of prothesis users and sensory impaired patients would likely be revolutionary to the field and would significantly improve the quality of life of its users. Such a device would also be ground-breaking in the fields of teleoperated robots and virtual reality as the key sensations of the hand would be completely communicated artificially through mechanical means.

**Reviewer #2:**

*“The authors systematically report recent advances in wearable biosensing gloves and sensory feedback devices in this review, and more specifically, it carries out the details of materials and mechanical structure to develop temperature, strain and pressure sensors that used in such systems, which have positive potentials in healthcare applications.”*

**Our Response:**

We thank the reviewer for the valuable comments and assessment of this review article.

**Comment #1:**

*In section 2.4.1, several examples of strain sensors were mentioned. Some directly related literatures may be cited to enrich the description. (e.g. Nature volume 587, pages 219-224 (2020), although the application demonstrated in this article was a sleeve, the anisotropically resistive mechanism was a good approach to achieve high gauge factors; Sci. Adv. 2021; 7 : eabe3778, the crease amplification effect described in this article can amplify the output signal of integrated strain sensors by three times, and it can be conformal and sticky to the hand, not as it stated in section 2.5).*

**Our Response:**

This is a great reference to include in our manuscript. We have included a description of this sensor in our manuscript.

**Modification to the first paragraph in the “Resistance, inductance, and transistor-based pressure sensors” Section:**

Although the following sensor was integrated onto an arm sleeve rather than a glove, we have included it in this review to highlight its novel approach. Araromi et al. made a soft, flexible strain sensor from uniaxially aligned carbon fibres pre-impregnated with an epoxy resin to form a CFPC lay-up. This mechanism can achieve high sensitivity with gauge factors greater than 85,000, and it is insensitive to bending and twisting deformations (Araromi et al. 2020).

**Comment #2:**

*Silica-based distributed fiber-optic sensor (DFOS) (Bai et al., Science 370, 848-852 (2020)) is an approach to provide feedback from external environment. How do authors compare it with three modes mentioned in section 3?*

**Our Response:**

We agree with the reviewer that this reference provides a unique perspective for our readers.

**Modification to the second paragraph of the “Wearable sensor gloves (WSGs)” Section:**

Researchers started to place exotic sensors on WSGs, enabling them to be used to detect anything from a pharmaceutical agent such as fentanyl (Barfidokht et al. 2019) to diverse biomarkers (Bariya et al. 2020) and perform hand joint location using silica-based distributed fiber-optic sensors (Bai et al. 2020).

**Comment #3:**

*Also, some related literatures may be cited for further discussion in section 3.2 and 3.3 regarding the relationship between biosystems design and mechanoreceptors, which provide us the sense of touch (e.g Nature volume 575, pages 473-479 (2019); Zhu et al., Sci. Adv. 2020; 6 : eaaz8693; Science volume 370, issue 6518, 768-769 (2020)).*

**Our Response:** We agree with the reviewer that this references could provide useful information to the reader.

**Modification to section 3 “Sensory Feedback Devices”:**

Healthy human hands are equipped with numerous mechanoreceptors which communicate to the brain the senses of touch, proprioception, and temperature (Science). People with sensory impaired or artificial limbs cannot determine the current state of their limbs through tactile and proprioceptive feedback as the loop between these mechanoreceptors and their brain is hindered; therefore, they rely on vision and memory to manipulate their limbs.

**Reviewer #3:**

*“This paper reviewed recent advances in wearable gloves especially with sensory feedback systems, including their applications in healthcare, prosthetics, robotics and virtual reality. The paper is overall well-written and provides insights into future development of future wearable glove-based devices. The paper is recommended for publication.”*

**Our Response:**

We thank the reviewer for the valuable comments and assessment of this review article.

**Comment #1:**

*The authors are recommended to briefly compare the biocompatibility, performance and stability of breathable materials used for wearable gloves. What materials is more preferred when it comes to long-term wearing?*

**Our Response:**

The reviewer has highlighted an aspect of the WSGs that we should further clarify. We have added some sentences to provide some guidance for readers.

**Modification to the first paragraph of the “Limitations and Challenges” Section:**

Overall, the material used to construct the glove needs to thin, breathable, biocompatible, and comfortable to improve the user experience. Fiber-based and textile-based materials excel in breathability, material cost, and mass production characteristics. Some material that meets these requirements are the following: nylon and polyester fabric, silk yarn, spandex and PTFE fibers (Li et al. 2018).

**Comment #2:**

*On Page 4, introduction, there is a typo in the sentence "from their hands to them another body part", should be "their other body part".*

**Our Response:**

We appreciate the reviewer pointing out the grammatical error. We changed the language in the manuscript to add clarity.

**Modification to the second paragraph of the “Introduction” Section:**

However, sensory impaired individuals need a device to transfer the sensory information from their hands to another body part.

**Comment #3:**

*The authors discussed different sensors and technologies for device integration in Figure 1. It may be meaningful to briefly summarize the current power sources of these wearable gloves. Are they mostly wire connected to an external power source, or uses portable batteries or wirelessly powered?*

**Our Response:**

The reviewer has highlighted a section that we did not properly cover. We have added a few sentences to comment on how wearable sensing gloves are powered.

**Modification to the first paragraph of the “Wearable sensing gloves (WSGs)” Section:**

The WSGs are powered using either a tethered connection or rechargeable batteries. Sensor data is recorded with a wireless or tethered data acquisition system depending on the use case.

**Comment #4:**

*In section 2.4. Research-based WSGs, the authors have mentioned several strain, pressure, and temperature sensors for wearable sensing gloves. It is recommended that the authors discuss more wearable gloves for biosensing applications especially biochemical sensing, such as monitoring metabolites in sweat. Some other prosthetic and healthcare applications such as wearables for human-machine interfaces may also be useful.*

**Our Response:**

As this manuscript is written for submission to the Biosensors and Bioelectronics journal, a section has been added to comment on wearable sensor gloves that have integrated biosensors for biochemical sensing.

**Modification to the “Research-based WSGs” Section through the addition of a new section:**

**2.4.4. Examples of biosensors**

This section details a few examples of WSGs that utilize biosensors, and there are only a few projects that utilize these types of sensors, as this is a new application for biosensors. Although not specific to WSGs, a few broad literature reviews were conducted to highlight the existing biosensors in wearable devices (Min et al. 2021; Sonawane et al. 2017). A more focused literature review was conducted by Hubble and Wang in 2018 to highlight the existing wearable sensing gloves that utilize electrochemical sensors with a focus on forensic, security, and defense applications. (Hubble and Wang 2019). Mishra et al. built a WSG utilizing an organophosphorus hydrolase-based biosensor for on-site detection of organophosphorus chemical threats, such as nerve-agent compounds. They built a highly stretchable, printed electrode system as a wearable point-of-use screening tool for defense and food security applications (Mishra et al. 2017). Luo et al. built a WSG utilizing carbon nanotube-based amperometric biosensors to detect lactate. A combination of CNT and Ag/AgCl is required for highly sensitive detection and this device can be used for healthcare and defense applications (Luo et al. 2018). Barfidokht et al. created a WSG for rapid, on-site detection of fentanyl to decentralize opioid testing using a chemical sensor made from flexible, screen-printed carbon electrodes modified with a mixture of multiwalled carbon nanotubes and a room temperature ionic liquid, 4-(3-butyl-1-imidazolio)-1-butanesulfonate (Barfidokht et al. 2019). There is a lot of opportunity for biosensors to be further integrated with WSGs for future applications.

**Comment #5:**

*For sensory feedback devices, what are the advantages and drawbacks of the three major feedback modes? It is recommended to briefly introduce their preferred application respectively.*

**Our Response:**

A couple of sentences were added to section 3.2 “Pros and cons of each feedback mode” stating the preferred applications of each mode.

**Modifications to the “Pros and cons of each feedback mode” section**

Hence, vibrations are most appropriate for short, occasional feedback as it can be sharp and clear, but can cause discomfort and desensitization with overuse.

The ideal applications of electric feedback are similar to those of vibrotactile feedback, with added considerations regarding electric hazards**.**

**Modifications to the fourth paragraph of the “Introduction” section:**

**The SFD portion of the literature review is divided into the following sections: introduction of feedback modes and review of electro-cutaneous, vibrotactile, and mechanotactile feedback; pros and cons of each feedback mode; and limitations, challenges, and future work.**