**Original Manuscript ID:** Access-2022-06028

**Original Article Title: “** Simulation and Classification of Spatial Disorientation in a Flight use-case using Vestibular Stimulation”

**To:** IEEE Access Editor

**Re:** Response to reviewers

Dear Editor,

Thank you for allowing a resubmission of our manuscript, with an opportunity to address the reviewers’ comments.

We are uploading (a) our point-by-point response to the comments (below) (response to reviewers), (b) an updated manuscript with yellow highlighting indicating changes (*Supplementary Material for Review*), and (c) a clean updated manuscript without highlights (*Main Manuscript).*

Best regards,

Foucher et al.

**Reviewer#1, Concern # 1:** Fore mostly, I would suggest authors to consider a thorough formatting correction to improve the overall readability of the article. For instance, Second paragraph of Experimental design section is out of order in terms of its formatting. Please check.

**Author response:** The ordering of the Experimental design section follows typical organization of introducing the experimental parameters which included axis motion, axis direction, and speed (sub, sup) in the first paragraph. The second paragraph describes the organization of a single trial in its' individual components, discussing the phases in detail. The third paragraph summarizes the trial organization using Figure 2A and 2B. The authors believed that the reader would not clearly understand the third summary paragraph if we put it before the second paragraph where the individual trial components were discussed initially. The fourth paragraph states the total number of specific stimulus trials over the entire experiment; this information is typically the last paragraph in the Experimental design section.

**Author action:** We updated the manuscript by ….shortening the first paragraph so that it is easier to read, discussion about the speed stimulus was condensed and moved to the appendix section. The first sentence of the third paragraph were combined with the second paragraph. The remaining part of the third paragraph was incorporated into the fourth paragraph. Now in the new version, the Experimental Design subsection contains a total of three paragraphs: explanation of experimental parameters, explanation of experimental trial parameters, the total number of specific stimulus trials over the entire experiment.



**Reviewer#1, Concern # 2:** Consider to follow IEEE Access reference style. List all references numerically in the order they've been cited within the paper. For instance, check the citation order in line 2 of second column in page one. It seem to be not matching the style here. ([2],[3],[4],[1],[5],[6]).

**Author response:** We used the LaTeX template to compile and arrange the reference section for the original submission in Word. The ordering [2],[3],[4],[1],[5],[6] is correct because we cite reference 1 in the Abstract. Reference 1 is cited in the Abstract because we quote a famous definition of SD from reference 1. The references are ordered in terms of relevance to the sentence, reference 2, 3, and 4 are more relevant in terms of listing the existing SD symptoms than reference 1.

**Author action:** We updated the manuscript by …removing the citation of the quote from the Abstract and kept the original ordering of the citations for the first paper citations.



**Reviewer#1, Concern # 3:** I would suggest authors to revisit ﬁgure captions and use it eﬀectively. (long captions shall be avoided wherever applicable)

**Author response:** We thank the reviewer for mentioning that the Figure captions are too lengthy, the authors also believe that shorter Figure and Table captions would be more effective for readers to quickly and clearly understand information.

**Author action:** We updated the manuscript by ….removing detailed explanation of figures from the captions, and incorporating important figure explanations in the document text. We have reduced the caption descriptions for Figure 1, 2, 5, and 6. The captions for Table 1 and 2 have also been reduced.



**Reviewer#1, Concern # 4:** The motion simulation system and the participants details are clearly explained and enables the reproducibility of the proposed work presented in this article.

**Author response:** We thank the reviewer for taking the time to confirm the correctness of the experimental design and participant details explanations.

**Author action:** We updated the manuscript by ….not changing any of the text related to the motion simulation system and participant details, as the reviewer states that the given explanation was sufficient for reproducing the experiment.



**Reviewer#1, Concern # 5:** I would suggest authors to use larger image for Figure 3. (for better visual from readers perspective)

**Author response:** The authors thank the review for their suggestion to provide a larger visual of Figure 3.

**Author action:** We updated the manuscript by ….providing a larger image on page 2 of the revised manuscript.



**Reviewer#1, Concern # 6:** The analysis section seem to be well done eﬀort as the measured data is numerically confirmed and checked for defects.

**Author response:** We thank the reviewer for taking the time to confirm the correctness of the per-processing and standardization procedure that we used to check the data for numerical correctness.

**Author action:** We updated the manuscript by ….not changing explanations related to the per-processing and standardization procedure in the analysis section.



**Reviewer#1, Concern # 7:** The response categorization and detection performance seem to provide conclusive evidence for the user experience experiment conducted in this study. Please check equation 1. Seems like an image. Please follow the journal template to add equations.

**Author response:** The authors thank the reviewer for pointing out that equation 1 is not correctly displayed in equation notation.

**Author action:** We updated the manuscript by ….using the LaTeX template instead of the Word template to ensure that no software compatibility issues for LibreOffice and Word are reflected in the final IEEE pdf document. We use the standard equation notation in LaTeX to display all equations correctly.



**Reviewer#1, Concern # 8:** Authors also have provided an useful evaluation details for the classiﬁcation model.

**Author response:** The authors are pleased to hear that the subsection (E. CLASSIFICATION MODEL EVALUATION) was useful for understanding how the classification models were evaluated.

**Author action:** We updated the manuscript by ….not making major changes to the explanations in subsection E. CLASSIFICATION MODEL EVALUATION. To make the explanations more in alignment with current Data Science research, common equations such as accuracy were removed and references are given.



**Reviewer#1, Concern # 9:** The result section looks good.

**Author response:** We are pleased that the organization and explanations of the result section are clear and sufficient

**Author action:** We updated the manuscript by ….keeping the same organization of the result section. We have only drastically changed the text in subsection C. SD CLASSIFICATION, because a more current and concise classification analysis that conformed to Data Science research standards was recommended.



**Reviewer#1, Concern # 10:** The conclusion section seem to be extremely lengthy. I would suggest authors consider a discussion section to highlight the ﬁndings and list out the advantages of the study made in this article. Also indicated the limitations of this study followed by conclusion.

**Author response:** We thank the reviewers for suggesting how to improve reader clarity and understanding of our work by adding an additional Discussion section. We agree that by highlighting the findings, and listing the advantages and limitations of the study will greatly help readers to understand the research.

**Author action:** We updated the manuscript by ….adding a Discussion section as recommended by the reviewer. In the discussion section we highlight the findings, list the advantages of the study with respect to past research from various research field, and explain the limitations of our work. Regarding the conclusion, we have shorted the text for each paragraph, but kept the paragraph organization of: restating the goal/approach/significance of the work, summary of experimental motion detection results, summary of the classification modeling results, summary of the experimental questionnaire as a viable measure for SD.



**Reviewer#1, Concern # 11:** Does the paper contribute to the body of knowledge?: Yes

**Author response:** The authors are pleased that the reviewer acknowledges that this paper contributes to the field of multi-disciplinary studies on SD and human behavior/activity.

**Author action:** We updated the manuscript by ….not changing explanations related to the contribution of this work.



**Reviewer#1, Concern # 12:** Is the paper technically sound?: Partially Yes. This paper presents a study of an in ﬂight piloting use case experiment and ML model prediction.

**Author response:** The reviewer does not explain why the paper is partially technically sound in his/her opinion, nor provide examples about how we can improve the content of the paper such that it is technically sound from their viewpoint. We believe that the reviewer may interpret the paper as partially sound, even though the analysis was executed correctly, because the original paper lacked a concrete explanation of our intentions and motivations regarding measurement, feature, and model selection.

Below are several sentences explaining why we selected models and features in the initial version of the paper, such that the reviewer is aware of our initial intentions. The goal of the paper was to use tools in a minimalistic manner, both experimental and numerical, such that reproduction of this work could be easily implemented in a real aviation cockpit without adding any additional sensors. The joystick was selected as a measure to capture disorientation perception instead of IMU sensors and/or a camera because the joystick is an existing cockpit instrument that is an extension of the pilot; no addition sensors or tools would need to be installed or approved. The features selected are proven characterizations that capture human motion and control. For example measuring position, velocity, acceleration, and jerk profiles of human movement during arm and hand coordination have been proven to be explanatory markers for human behavior and energy expenditure in the fields of human movement psychology and human-in-the-loop control theory. The goal of this research was to use proven markers of human behavior used in human-in-the-loop controls and investigate the viability of these markers as key features for perceptual disorientation. Investigating the usefulness of common place features that are currently used in the field of aviation with newer numerical tools (e.g. AI, ML, DL), is a typical scientific process of advancing technology and domains of knowledge with respect to societal and technological advancements. Eight fundamental and currently used ML algorithms, in their simplest constructions, were selected for comparison to understand which features function better with specific model constructions, give explanations for why they function well together, and give recommendations for future features and models that might predict SD well.

**Author action:** We updated the manuscript by ….re-selecting the models and features in a way that is more in-alignment with current Data Science research. The models are selected to represent a specific type of model architecture; decision-tree, non-decision tree, and deep-learning. The comparison of the three superior models for SD data, as opposed to a survey of 8 models will improve the focus and clarity of the paper. More accurate names, definitions, and explanations about models are provided with current supporting citations.



**Reviewer#1, Concern # 13:** Is the subject matter presented in a comprehensive manner?: Partially Yes. Although paper is presented in a easy-to-read manner, there are some concerns with respect to presentation style (lengthy paragraphs) and format.

**Author response:** We thank the review for explaining why they believe that the subject matter is presented in a partially comprehensive manner. We understand that long paragraphs and formatting can detract from quickly understanding the content.

**Author action:** We updated the manuscript by ….shortening paragraphs and explanations such that the subject matter is presented in a more direct and comprehensive manner.



**Reviewer#1, Concern # 14:** Are the references provided applicable and suﬃcient?: Superﬁcially yes. However, Recent times milestone paper seems to be missing in the reference list. I would suggest authors consider latest publications on similar grounds.

**Author response:** The authors thank the reviewer for mentioning that some recent and/or important topic relevant papers should be cited in our paper.

Before submitting the paper we searched the Internet for the most recent papers published on the topic of experimental modeling of SD. The most recent paper that was published relating to the multi-disciplinary topic of experimental modeling of SD was a 2020 IEEE Access paper titled 'A Classification Method for Unrecognized Spatial Disorientation Based on Perceptual Process'. In fact, this recent paper on SD motivated us to submit our paper to IEEE Access. We believed that perhaps there was an audience of readers that were interested in SD at IEEE Access, and readers might be interested in a psychophysical and ML modeling perspective in addition to a neuroscience perspective that was given in the paper. We did not cite their paper because they explained SD from a neuroscience perspective, and we believed that switching between neuroscience and psychophysical motivations would distract the reader, when our goal was to only discuss a psychophysical perspective of SD.

Since our paper topic is of a multi-disciplinary nature, and includes research from the fields of whole-body motion detection, psychology/physiology, signal processing, control theory, human activity, and most recently artificial intelligence. The authors interpret the reviewer’s feedback of “Superficially”, as we lacked references pertaining to the individual research fields of whole-body motion detection, psychology/physiology, signal processing, control theory, human activity, and artificial intelligence. Therefore, providing references for up-to-data multi-disciplinary papers on the topic of SD are insufficient for the IEEE Access audience. Based on recent past successful publication in other conferences and journals on the topic of SD, using only multi-disciplinary SD references, we mistakenly believed that providing multi-disciplinary references linked to SD would be sufficient.

**Author action:** We updated the manuscript by ….first performing a literature review on the following fields of research:

* psychology/physiology with respect to whole-body motion detection,
* signal processing for the treatment of joystick signals,
* control theory for inspiration of AI modeling features,
* artificial intelligence for modeling architecture and feature selection,
* human activity,
* multi-disciplinary experimentation and modeling of SD.

The authors believe that the new manuscript references the most up-to-date scientific work in the six fields of research related to our work.



**Reviewer#1, Concern # 15:** Are there references that are not appropriate for the topic being discussed?: No

**Author response:** The authors thank the reviewer for confirming that our references were correctly selected and used for our topic of research.

**Author action:** We updated the manuscript by ….applying the same logic and careful consideration of referencing with respect to the research topics for newly added ‘recent field specific’ references (psychophysical motion detection, signal processing, control theory, AI, human activity, multi-disciplinary SD). Additionally, if an existing older reference could be replaced by a newer reference, the older reference was removed.



**Reviewer#2, Concern # 1:** Major concern:Given only traditional ML model was applied, the conclusion "no significant relationship between physical disorientation and motion detection was found." might be true. However, what about some deep learning model? I don't think the 2-layer NN mentioned in the paper should be identified as a deep model. I think the discussion of deep learning models will be helpful. If not, deep-diving into the reason why physical disorientation and motion detection is not strongly related is necessary.

**Author response:** The authors thank the reviewer for stating that the 2-layer NN model was insufficient Deep Learning model representation. We choose the simplest construction of a NN model because our goal was to compare model architecture with respect to features, using model predictive performance as an indicator to discriminate one fundamental model architecture from another. By selecting a 2-layer NN the model would be in its most simplest fundamental form, such that we could then compare its performance with other models in their simplest fundamental constructions as well. Following the principle of ‘Occam’s Razor’, the simplest fundamental form is desired and represents the type of model.

There are many ways to tune a classification model, the principle ways are to: 1. use a different model for the given features, 2. use different features for a given model, 3. optimize the hyperparameters of the model. The goal of our work was to investigate option 2, to understand which feature constructions were viable for a given fundamental model architecture. And, then given the fundamental model architecture which algorithmic differences give rise to differences in prediction. For example, fundamental model architectures that divide the subspace like decision trees in comparison to architectures that do not divide the subspace like SVM give different predictions for specific features, based on this simple algorithmic difference.

However, we understand that the majority of AI research is focused on option 1, where different model constructions are constructed for given features. Therefore, to conform with the mainstream interest of the developing more advanced model constructions, we agree that selection of a superior Deep Learning model for time-series data would be more appropriate, than investigating types of model constructions in their simplest form.

Unfortunately, the reviewer did not state which Deep Learning model for time-series data would be most appropriate in there opinion. We sent a letter to the editor asking for more clarity about which Deep Learning model would be sufficient for our analysis.

**Author action:** We updated the manuscript by ….using an LSTM model as a representative Deep Learning model. We selected LSTM over 1D CNN model constructions because the memory parameter was of interest in providing understanding about human behavior with respect to the causal connection of sequential events. In addition, instead of comparing many models, our eight selected models, with slightly similar model fundamental constructions we only select three superior models to represent a specific model category, such as decision-tree, non-decision tree (SVM), and Deep Learning (LSTM). Contrary to literature, we investigate decision-tree as a viable model architecture because we investigate different data transformations to create features that are suitable for decision-tree models.



**Reviewer#2, Concern # 2:** Minor suggestion:1. Introduction is too long and hard to follow. I suggest dividing it into two parts, introduction and related work.

**Author response:** We graciously thank the reviewer for this organizational recommendation. The authors agree that the organization of the paper will be greatly improved if the problem statement, minimal background information, and our approach to addressing the problem are only included in the INTRODUCTION. More detailed motivational explanations of the field of SD would be better suited in a separate RELATED WORKS section.

**Author action:** We updated the manuscript by ….adding a RELATED WORKS section after the INTRODUCTION, as recommended by the reviewer. In the RELATED WORKS section we explain detailed background information about the study of SD in the field of aviation, and motivate why the field of aviation is interested in monitoring and predicting SD behavior in a functional aviation context. The INTRODUCTION is now more streamlined and discusses: the problem statement, recent SD research, our approach to solving the problem in a complementary way to previous multi-disciplinary research.



**Reviewer#2, Concern # 3:** Minor suggestion: 2. For related work, authors can talk about some other applications that use IMUs/motion detection. It is helpful for readers to understand this ﬁeld. For example, [1-3] are some high-impact applications including gait monitoring, human pose estimation, and human activity recognition using IMUs.

1. An, Sizhe, et al. "Mgait: Model-based gait analysis using wearable bend and inertial sensors." ACM Transactions on Internet of Things 3.1 (2021): 1-24.

2. Von Marcard, Timo, et al. "Sparse inertial poser: Automatic 3d human pose estimation from sparse imus." Computer Graphics Forum. Vol. 36. No. 2. 2017.

3. Xiao, Fanyi, et al. "A deep learning method for complex human activity recognition using virtual wearable sensors." International Conference on Spatial Data and Intelligence. Springer, Cham, 2020.

**Author response:** We agree with the reviewer that additional discussion should be given to other human activity measures, such as IMU and pose estimation using a camera. And we thank the reviewer for taking the time to recommend several relevant and well-known papers in the field of human activity monitoring.

Our motivations for selecting joystick and questionnaire measures to capture human behavior were driven by an industrial request to use existing equipment in an aviation cockpit. Prediction of SD in a real aviation cockpit setting without adding any additional senors would be useful, save lives without costing a lot of money, from a practical industrial viewpoint. We considered using IMU and pose estimation using a camera, and both IMU and pose estimation results captured task relevant behavior in real flight. For this initial research study we opted to use a joystick because it is a proven measure used to capture small changes in human perception and behavior, we required a sensitive measure because participant were already semi-constrained in a seated position.

**Author action:** We updated the manuscript by ….adding a subsection called HUMAN ACTIVITY MEASUREMENTS, in the RELATED WORKS section, discussing the types of measurements used in the field of human activity and behavior. Additionally, we more clearly explain our motivations for selecting the joystick and questionnaire measures, and discuss the usefulness of IMU and pose estimation measures in the context of our experimental paradigm.



**Reviewer#2, Concern # 4:** Minor suggestion: 3. Conclusion is too long and hard to follow. I suggest dividing it into two parts, discussion, and conclusion.

**Author response:** The authors thank the reviewer for stating that the conclusion is too lengthy and difficult to follow. We agree that the readability of the paper could be greatly improved if we added a Discussion section and shorted the Conclusion section.

**Author action:** We updated the manuscript by ….adding a Discussion section as recommended by the reviewer. In the discussion section we highlight the findings, list the advantages of the study with respect to past research from various research field, and explain the limitations of our work. Regarding the conclusion, we have shorted the text for each paragraph, but kept the paragraph organization of: restating the goal/approach/significance of the work, summary of experimental motion detection results, summary of the classification modeling results, summary of the experimental questionnaire as a viable measure for SD.



**Reviewer#2, Concern # 5:** Additional Questions: 1) Does the paper contribute to the body of knowledge?: Yes

**Author response:** The authors are very pleased to hear that the reviewer confirms that our work contributes to the field of multi-disciplinary research on SD and human behavior/activity.

**Author action:** We updated the manuscript by ….not changing explanations related to the contribution of this work.



**Reviewer#2, Concern # 6:** Additional Questions: 2) Is the paper technically sound?: Yes

**Author response:** The authors thank the review for confirming that the paper is technically sound.

**Author action:** We updated the manuscript by ….not changing the experimental section. In the revised manuscript we improve the technical quality of the classification methods by re-selecting the models and features in a way that is more in-alignment with current Data Science research. The models are selected to represent a specific type of model architecture; decision-tree, non-decision tree, and deep-learning. The comparison of the three superior models for SD data, as opposed to a survey of 8 models will improve the focus and clarity of the paper. More accurate names, definitions, and explanations about models are provided with current supporting citations.



**Reviewer#2, Concern # 7:** Additional Questions: 3) Is the subject matter presented in a comprehensive manner?: Somewhat

**Author response:** The authors thank the reviewer for his/her honest opinion. It is unclear as to how we can improve the subject matter presentation such that it is comprehensive to the reviewer.

However, based on detailed explanations by reviewer 1, perhaps the paragraph and sentence constructions were too lengthy. Additionally, we interpreted ‘Somewhat comprehensive’ as the subject matter was lacking in clear explanations about: the problem statement, our intentions/approach for solving the problem, our contribution with respect to previous work on multi-disciplinary SD and within each related domain of research (psychophysical motion detection, signal processing, control theory, AI), and limitations of our work.

**Author action:** We updated the manuscript by ….making the paragraphs and sentences more succinct and clear. In addition, we shortened the INTRODUCTION so that it clearly details the problem statement, our intentions/approach for solving the problem, our contribution with respect to previous work on multi-disciplinary SD. Similarly, we added a DISCUSSION section where we discuss the main points of our results, our contribution with respect to each related domain of research, and limitations of our work.



**Reviewer#2, Concern # 8:** Additional Questions: 4) Are the references provided applicable and sufficient?: Somewhat

**Author response:** The authors interpret the reviewer’s feedback of “Somewhat”, as we lacked recent references pertaining to the individual research fields of whole-body motion detection, psychology/physiology, signal processing, control theory, human activity, and artificial intelligence.

**Author action:** We updated the manuscript by ….first performing a literature review on the following fields of research:

* psychology/physiology with respect to whole-body motion detection,
* signal processing for the treatment of joystick signals,
* control theory for inspiration of AI modeling features,
* artificial intelligence for modeling architecture and feature selection,
* human activity,
* multi-disciplinary experimentation and modeling of SD.

The authors believe that the new manuscript references the most up-to-date scientific work in the six fields of research related to our work.



**Reviewer#2, Concern # 9:** Additional Questions: 5) Are there references that are not appropriate for the topic being discussed?: No

**Author response:** The authors thank the reviewer for confirming that our references were correctly selected and used for our topic of research.

**Author action:** We updated the manuscript by ….applying the same logic and careful consideration of referencing with respect to the research topics for newly added references. Additionally, if an existing older reference could be replaced by a newer reference, the older reference was removed.



**Reviewer#2, Concern # 9:** If you have any questions, please contact article administrator: Mr. Nishant Shukla n.shukla@ieee.org

**Author response:** The authors thank the reviewer for providing their email address. The authors had questions and concerns about the reviewer’s major concern, regarding the selection of a more appropriate Deep Learning model for human movement data. We followed the standard journal protocol and respectfully contacted the Editor, as a neutral party in the peer review process, asking how to best respond to two points. The two points entailed: 1) how to better explain that the physical disorientation measures were not related to modeling; the physical and perceptual disorientation result was based on statistical analysis, 2) which Deep Learning model architecture is sufficient for this analysis, would any one of the 1D CNN, LSTM, or Transformer Attention deep learning models be sufficient as a Deep Learning model representative.

We did not want to jeopardize the acceptance of our paper by not following the peer review process, where the authors are not allowed to have direct solitary contact or involvement with the reviewers. However the Editor can serve as a neutral party and convey the concerns of the reviewers and authors to the respective party.

**Author action:** We updated the manuscript by ….implementing the proposed information in our letter to the Editor asking for advise about how to respond to the two points; the two points were about how to effectively convey the physical and perceptual disorientation result without causing confusion, and which Deep Learning model architecture is sufficient for this multi-disciplinary survey of AI methods for SD. The proposed points mentioned in the letter were: “What we could propose is to ... (2) be clearer about the relation between motion detection and physical disorientation as it is in our analysis to avoid the current misunderstanding, (3) dig deeper in the discussion about how to further investigate this relation through deep learning models in future research.”



***Note:*** *References suggested by reviewers should only be added if it is relevant to the article and makes it more complete. Excessive cases of recommending non-relevant articles should be reported to ieeeaccesseic@ieee.org*