README

Dense 3D pressure discomfort threshold (PDT) map of the human head, face and neck [Dataset]

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1. GENERAL INFORMATION

1.1. Title of Dataset

Dense 3D pressure discomfort threshold (PDT) map of the human head, face and neck [Dataset]

1.2. Author information

In case of questions regarding the data files and data processing methods, please contact Toon Huysmans. For questions regarding study method and publication, please contact Maxim Smulders.

Author/Lead Investigator/Data analyst
Name: Maxim Smulders
ORCID: 0000-0001-9957-0991

Institution: Delft University of Technology
Address: Landbergstraat 15, 2628CE Delft, The Netherlands
Email: m.smulders@tudelft.nl

Author/Investigator
Name: Lisanne N.M. van Dijk
ORCID: 0000-0002-8626-7296

Institution: Crescent Medical B.V.
Address: Vlamingstraat 72A, 2611KZ Delft, The Netherlands

Author/Investigator/Data analyst
Name: Yu (Wolf) Song
ORCID: 0000-0002-9542-1312

Institution: Delft University of Technology
Address: Landbergstraat 15, 2628CE Delft, The Netherlands
Email: y.song@tudelft.nl

Author/Investigator
Name: Peter Vink
ORCID: 0000-0001-9985-3369

Institution: Delft University of Technology
Address: Landbergstraat 15, 2628CE Delft, The Netherlands
Email: p.vink@tudelft.nl

Author/Principal Investigator/Lead data analyst
Name: Toon Huysmans
ORCID: 0000-0001-7053-6458

Institution[1]: Faculty of Industrial Design Engineering, Delft University of Technology
Address[1]: Landbergstraat 15, 2628CE Delft, The Netherlands
Email[1]: t.huysmans@tudelft.nl

Institution[2]: Imec-Vision Lab, Department of Physics, University of Antwerp
Address[2]: Universiteitsplein 1, B-2610 Antwerp, Belgium

1.3. Date of data collection
2019-06-12 till 2019-06-28

1.4. Geographic location of data collection
Delft, The Netherlands

1.5. Funding sources
Information about funding sources that supported the collection of the data can be found in Table 1.

Table 1 | Funding sources Smulders et al. (2022)

Funding source	Type of funding	Project number
Crescent Med	Supporting this study by making manhours available	–
Dutch Research Council (NWO)	Partly financed	18636
Delft University of Technology	Predominantly funded (man hours, lab, lab equipment, software licences, data storage, etc.)	–

1.6. Ethical approval
This study was approved by the Delft University of Technology Human Research Ethical Committee (hrec.tudelft.nl) on 18 July 2019 (approval no. 772), in accordance with The Helsinki Declaration (World Medical Association, 2013). Research materials and method, including a 'sticker allergic reaction test', were evaluated with a medical doctor and approved by a Health, Safety and Environment Officer of the Delft University of Technology.

Participants recognisable on pictures and 3D scans gave explicit permission to be recognisable in this publication. Other models are maps on a generic head model made of merging all 3D scans of all participants into one.

2. SHARING/ACCESS INFORMATION

2.1. Licenses/restrictions placed on the data

Attribution (CC BY 4.0). See also creativecommons.org/licenses/by/4.0/ for the full license.

2.2. Links to publications that cite or use the data

Smulders, M., van Dijk, L.N.M., Song, Y., Vink, P. and Huysmans, T. (2022) Dense 3D pressure discomfort threshold (PDT) map of the human head, face and neck: a new method for mapping human sensitivity. *Applied Ergonomics*, 107 (103919). https://doi.org/10.1016/j.apergo.2022.103919

2.3. Data derived from other sources

The SSM (from Principal Component 1 to PC50, ±3σ) was built with the CAESAR 3D Anthropometric Database (USA, Italy and The Netherlands, male and female, 18-65y, n=4309) by Robinette, K. M., Blackwell, S., Daanen, H., Boehmer, M., & Fleming, S. (2002). *Civilian American and European surface anthropometry resource (CAESAR).* The CAESAR dataset can be acquired at Shape Analysis:

Shape Analysis
Website: https://www.shapeanalysis.com/CAESAR.htm
Phone: +44 (0) 7720851196
Email: richard@shapeanalysis.com

Please note that 117 3D scans from CAESAR could not be processed and were excluded from our model. Thus where the original dataset contains 4426 samples, this study used 4309.

2.4. Recommended citation for this dataset

Smulders, M., van Dijk, L.N.M., Song, Y., Vink, P. and Huysmans, T. (2022) Dense 3D pressure discomfort threshold (PDT) map of the human head, face and neck [Dataset]. In: 4TU.ResearchData. https://doi.org/10.4121/21482328

3. DATA & FILE OVERVIEW

3.1. File List

Figure 1 | File list for Smulders et al. (2022) Dense 3D pressure discomfort threshold (PDT) map of the human head, face and neck [Dataset]

File name	File type	Brief description	Contents
Smulders (2022) TUDELFT PDT_Mean_nonNorm.vtk	*.vtk	**Non-normalised** PDT (pressure discomfort threshold) data mapped on a TU Delft developed 3D geometry model of the human head, face and neck based on an mirrored average of 28 participants from Smulders et al. (2022). This model allows for 3D viewing PDT maps based on Smulders et al. (2022).	PDT_all_mean PDT_all_std PDT_male_mean PDT_male_std PDT_female_mean PDT_female_std PDT_participant_01-29 (excl. 14)
Smulders (2022) TUDELFT PDT_Mean_nonNorm.csv	*.csv	**Non-normalised** PDT data for each 3D point (x-, y-, z-coordinate) of a Smulders et al. (2022) based 3D geometry model of the human head, face and neck.	"
Smulders (2022) TUDELFT PDT_Mean_Norm.vtk	*.vtk	**Normalised** PDT (pressure discomfort threshold) data mapped on a TU Delft developed 3D geometry model of the human head, face and neck based on an mirrored average of 28 participants from Smulders et al. (2022). This model allows for 3D viewing PDT maps based on Smulders et al. (2022).	PDT_all_mean PDT_all_std PDT_male_mean PDT_male_std PDT_female_mean PDT_female_std PDT_participant_01-29 (excl. 14)
Smulders (2022) TUDELFT PDT_Mean_Norm.csv	*.csv	**Normalised** PDT data for each 3D point (x-, y-, z-coordinate) of a Smulders et al. (2022) based 3D geometry model of the human head, face and neck.	"
Smulders (2022) CAESAR PDT_Mean_nonNorm.vtk	*.vtk	**Non-normalised** PDT (pressure discomfort threshold) data mapped on a CAESAR (Robinette et al., 2002) based 3D geometry model of the human head, face and neck, of which principle components (PC) can be adjusted. This model allows to create custom Eigenmodels based on the CAESAR database with PDT maps based on Smulders et al. (2022).	Model_Eigenmode_0001-0050 PDT_all_mean PDT_all_std PDT_male_mean PDT_male_std PDT_female_mean PDT_female_std PDT_participant_01-29 (excl. 14)
Smulders (2022) CAESAR PDT_Mean_nonNorm.csv	*.csv	**Non-normalised** PDT data for each 3D point (x-, y-, z-coordinate) of a CAESAR (Robinette et al., 2002) based 3D geometry model of the human head, face and neck.	"

Smulders (2022) CAESAR PDT_Mean_Norm.vtk	*.vtk	**Normalised** PDT (pressure discomfort threshold) data mapped on a CAESAR (Robinette et al., 2002) based 3D geometry model of the human head, face and neck, of which principle components (PC) can be adjusted. This model allows to create custom Eigenmodels based on the CAESAR database with PDT maps based on Smulders et al. (2022).	Model_Eigenmode_0001-0050 PDT_all_mean PDT_all_std PDT_male_mean PDT_male_std PDT_female_mean PDT_female_std PDT_participant_01-29 (excl. 14)
Smulders (2022) CAESAR PDT_Mean_Norm.csv	*.csv	**Normalised** PDT data for each 3D point (x-, y-, z-coordinate) of a CAESAR (Robinette et al., 2002) based 3D geometry model of the human head, face and neck.	"
Smulders (2022) OBJ PDT_maps.zip	*.zip (*.obj)	This ZIP folder contains OBJ (geometry definition file format) files for use in CAD (computer-aided design).	Non-normalised and normalised version for CAESAR as TUDELFT 3D geometry models: PDT_all_mean PDT_all_std PDT_male_mean PDT_male_std PDT_female_mean PDT_female_std
Smulders (2022) Original PDT_data.zip	*.zip (*.obj & *.vtk)	This ZIP folder contains the cleaned original PDT and landmark ID data of all participants, and the 3d geometry model based on all participants in the study of Smulders et al. (2022).	original_Head (*.obj) Original_PDT_participant_01-29 (*.vtk)
Smulders (2022) Participant_characteristics.csv	*.csv	Participant characteristics and anthropometry of Smulders et al. (2022).	Participant ID Gender [male/female/x] Nationality Age [years] Stature length [cm] Weight [kg]

" = Similar as above.
Note: all *.vtk files are in ASCII. These can be opened in most text editors.

3.1.1. Relationship between files

Participant numbers in all files correspond to the same participant.
*.csv files of the same name as the *.vtk files contain similar data, but store data differently. Where *.csv are comma separated values which can be opened in spreadsheets or text editors, *.vtk is an ASCII file which can be opened in VTK supported programs (e.g. ParaView) and text editors.

3.2. Excluded data

3D geometry of individual participants is excluded for privacy reasons and will not be provided outside of the research team, as stated in the Informed Consent agreement with participants and in line with the Human Research Ethics Committee of the Delft University of Technology (TU Delft) ruling.

4. METHODOLOGICAL INFORMATION

4.1. Description of methods used for collection/generation of data

This method is described in *Smulders, M., van Dijk, L.N.M., Song, Y., Vink, P. and Huysmans, T. (2022) Dense 3D pressure discomfort threshold (PDT) map of the human head, face and neck: a new method for mapping human sensitivity. Applied Ergonomics, 107 (103919). https://doi.org/10.1016/j.apergo.2022.103919*

Pressure Discomfort Threshold (PDT) was measured in 28 healthy subjects on 126 to 146 landmarks (135 on average) on the left side of the head, face and neck. No repeated trials were conducted. The landmarks' 3D coordinates of each participant were captured by means of 3D scanning and mapped to a reference head. The PDT values of all participants were bilaterally mirrored and interpolated to create a complete 3D PDT map of the human head, face and neck.

4.1.1. Participants

14 female and 14 male (14 Dutch, 6 Chinese, 3 Italian, 1 Costa Rican, 1 Thai, 1 American, 1 Belgian and 1 Danish-German) adults with no history of a stroke, epilepsy, seizure, stenosis, and/or injuries or physical complaints at the face, neck and/or head in the past six months participated in this study (see Table 2). Participants with tape and/or glue allergies were excluded from the experiment, as sticker landmarks were used on the skin.

Table 2 | Characteristics of participants.

		Mean	SD
Female (n=14)	Age [Years]	35.4	14.4
	Stature [cm]	168.5	5.0
	Weight [Kg]	59.2	7.8
Male (n=14)	Age [Years]	31.5	11.9
	Stature [cm]	179.1	9.5
	Weight [Kg]	73.6	7.9

Please note that subject no. 14 is excluded from all datasets, due to incompletion of the experiment by this participant (due to a computer error with data loss and insufficient time to complete).

The full dataset on participant characteristics (excl. subject no. 14) can be found in '*Smulders (2022) Participant_ characteristics.csv*'.

4.1.2. Apparatus

In this study, a Mecmesin AFG 500N pressure gauge was used to apply pressure stimuli perpendicular to the skin on landmarked locations (see Figure 2), capturing the PDT in Newtons.

A 3D printed ø10mm PLA pressure gauge probe with rounded edges (3mm fillet) (see Figure 2) was used to capture small facial features (e.g. nose tip) for a high-density measurement. Rounded edges were used to prevent high pressure at the surface edge. PLA (Polylactic acid) was chosen for its biocompatibility and low thermal conductivity regarding metal probes, as a cold sensation might influence thermal comfort of the user.

Ø12mm stickers were used as landmarks. A hair cap was used to hygienically cover the hair, in order to place a head-cap with an EEG 10-20 landmarks grid (Jasper, 1958) (see Figure 3Figure 4) to landmark the positions on the head. An Artec Eva was used to 3D scan the head, face and neck of participants, capturing both 3D geometry as textures (see Figure 5). Artec Studio software was used to capture 3D coordinates of placed landmark stickers. A Canon EOS 60D camera was used to make reference photos of the landmarks. A massage seat was used to support the head (preventing movement and muscle activation caused by giving counter-pressure) while probing PDT.

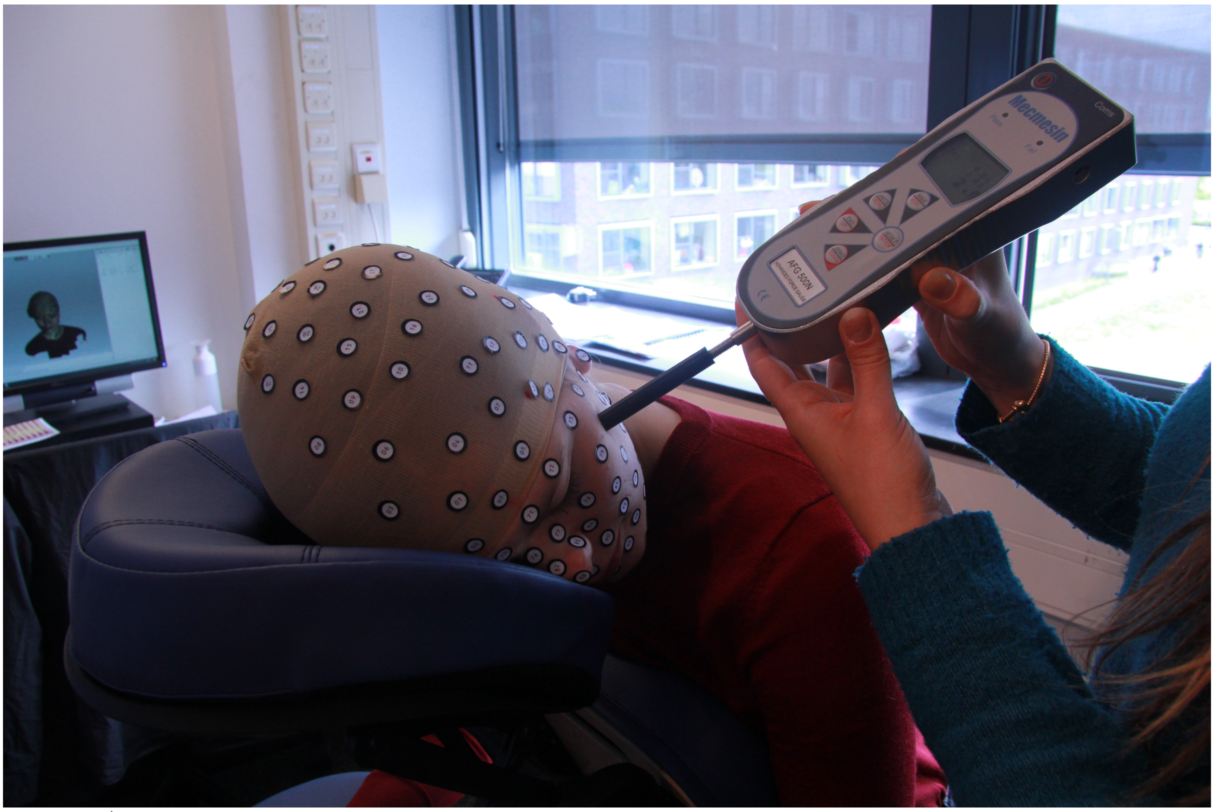

Figure 2 | Mecmesin AFG 500N pressure gauge with 3D printed PLA Ø10mm tip, and participant with EEG 10-20 landmark grid headcap and landmark stickers on the face, head and neck. Researcher gradually increasing pressure on a landmark with pressure gaug.

4.1.3. Procedure

Written consent was obtained prior to the experiment. Stature height and weight were measured, and age, gender and ethnicity/nationality were noted.

Landmark placement and capture

Participants were asked to clean their face and neck with hypoallergenic cleaning wipes for better landmark sticker adhesion. Researchers cleaned their hands with disinfectant alcohol gel. Participants with long hair were asked to make a bun to the right side of the head, next to the ear, to minimise influence of the hair on the 3D scan (in order to scan close to the actual scalp) and PDT measurements (see Figure 3).

Participants then sat down, where two researchers placed a clean hair cap over the hair and pushed hair underneath as much as possible. Next, the head-cap with the EEG 10-20 landmark grid was placed on top. 126 to 146 landmarks (135 on average) were placed by two researchers on the face and neck (see Figure 3). Some of these markers were placed based on clearly identifiable anatomical landmarks (e.g. tragus, lateralis ad alare, philtrum, protuberantia mentalis, and commissura labiorum, as indicated on a reference model), where others were at intermediate locations (see Figure 4). The goal was to gain a compact spread over the entire head, face and neck, with a distance of 2-3 cm between landmarks. Some participants with broad necks got an extra row of landmark-stickers in the back of the neck and some got extra landmarks around the ear to cover some ‘blind spots’.

With an Artec Eva 3D scanner, the geometry of the head, face and neck, and the landmark coordinates were captured (see Figure 5). Thereafter reference photos of the landmarks where made.

Figure 3 | Placing marker-stickers on the face and neck. The long hair of the participant was bound in a bun to the right side of the head, in order to scan the left scalp shape.

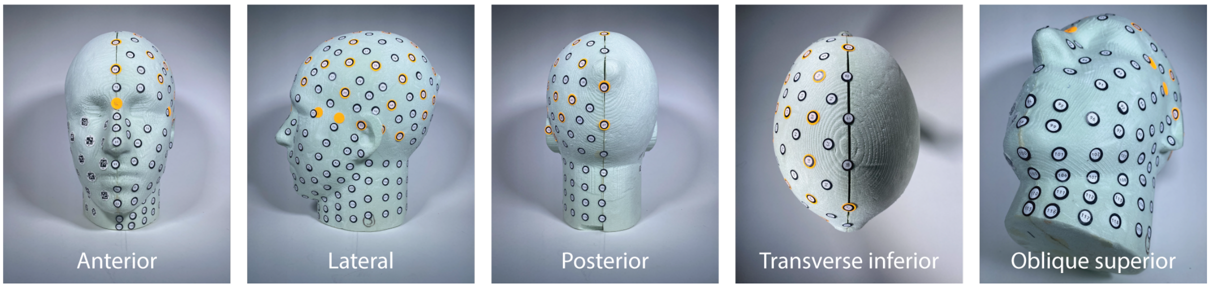

Figure 4 | Landmark location reference model (black markers only).

Figure 5 | 3D scanning the head, face and neck in order to capture the geometry and marker locations, using a rotating seat, Artec Eva 3D scanner and a reference monitor.

Sensitivity experiment procedure

All marker-points were divided over four zones, to limit the number of postural changes, which were passed in order. For pressure on the head (zone 1) and the back of the neck (zone 4), participants were asked to take position A (see Figure 6): with the face down on the head support. For pressure on the face (zone 2), participants were asked to take position B (see Figure 6): with the face sideways on the headrest, respectively. For pressure on the lower chin and neck front (zone 3), participants were asked to take position C (see Figure 6): sitting upright, respectively.

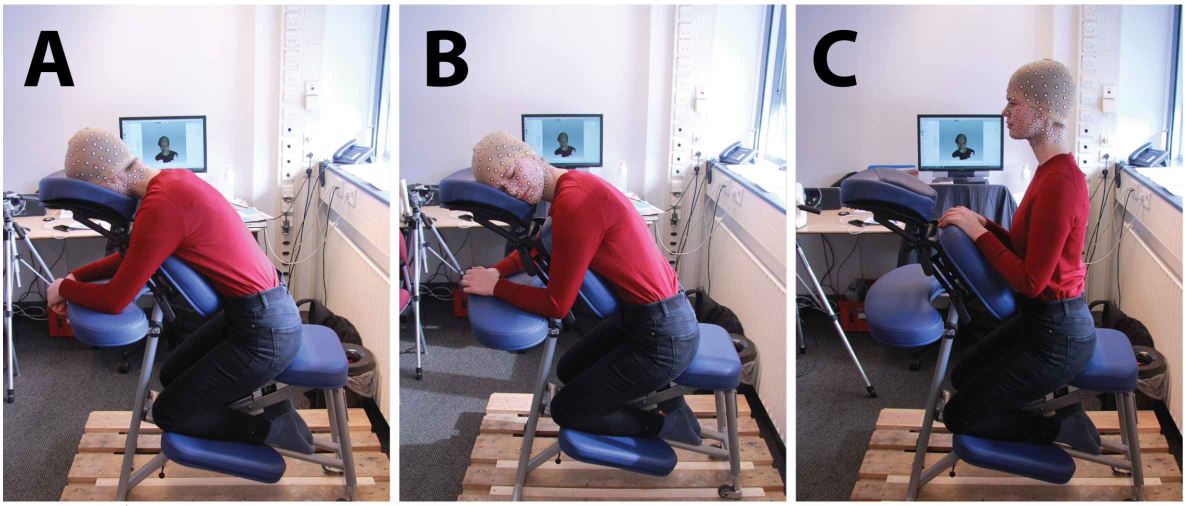

Figure 6 | Position A: subject in massage seat, face down. Position B: subject in massage seat, face sideways. Position C: subject in massage seat, head up.

The experiment was conducted in two sessions: the first was for priming, where participants got acquainted with the procedure with a limited number of landmarks being pressed. Thereafter participants were asked to stand up and have a five-minute break, to limit the impact of the priming on the second session. In the second session, all landmarks in each zone were probed in a randomised order and data was collected. For each landmark, a researcher gradually applied pressure on the centre of the landmark with the probe of the pressure gauge along the normal direction of the face/head/neck in this region (see Figure 2). Participants were instructed to slap with their hand on the arm rest when applied pressure was considered uncomfortable. Pressure was then released by the researcher and the recorded maximum force was documented.

4.2. Methods for processing the data

Below describes how the submitted data were generated from the raw or collected data. Software used for this can be found in Table 3.

Table 3 | Software used to process data

Software	Developer	Website
Artec Studio 14	Artec 3D	www.artec3d.com
Custom Phyton script (VTK library)	Toon Huysmans	–
Excel	Microsoft	www.microsoft.com
ParaView	Sandia National Laboratories Kitware Inc. Los Alamos National Laboratory	www.paraview.org
R3DS Wrap 3.4	Russian3DScanner LLC	www.russian3dscanner.com
Rhinoceros	Robert McNeil & Friends	www.rhino3d.com
Sensitivity Mapper (Phyton)	Toon Huysmans	–
VTK library	Kitware Inc.	www.vtk.org

4.2.1. 3D scan processing

In Artec Studio 14, 3D scans of each subject were pre-processed (e.g. fill holes), aligned and merged as a 3D textured mesh, which was exported in *.obj format.

4.2.2. 3D marker allocation and numbering

A Python program was developed to allocate the correct marker ID number to each landmark (see Figure 7). Marker IDs were visually identified based on the allocated number in the scan, or when illegible, the reference photos were used.

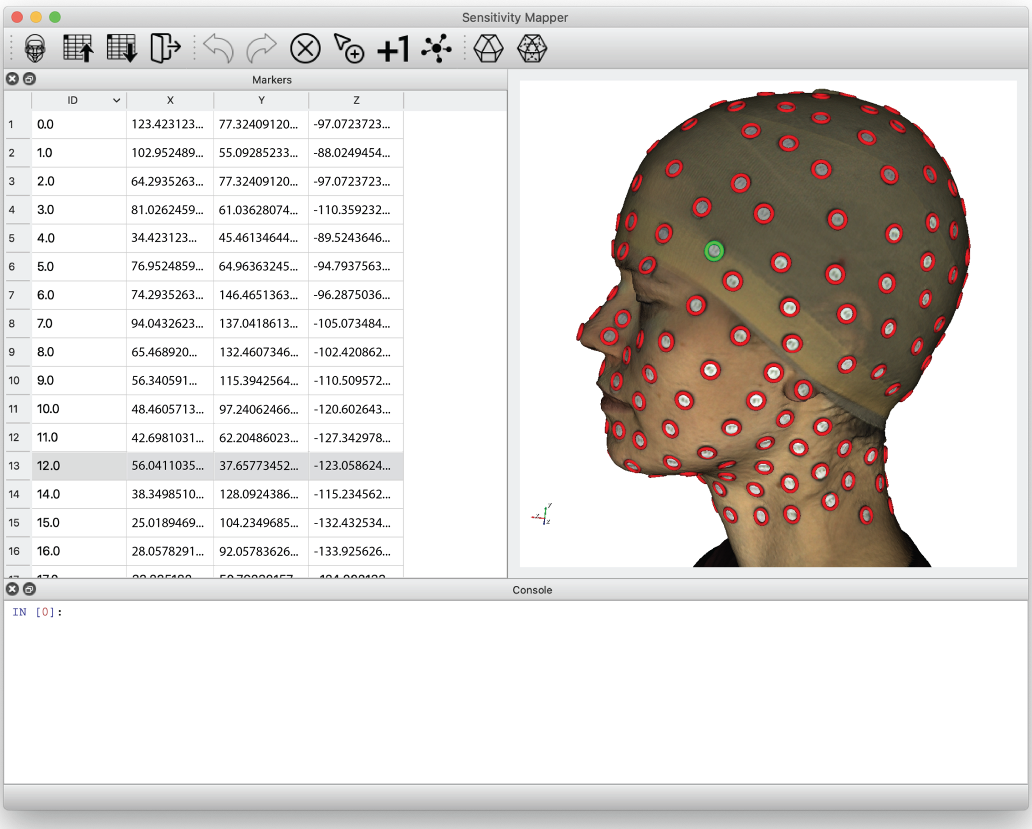

Figure 7 | Screenshot of 3D marker allocation and numbering program by T. Huysmans.

4.2.3. Intra-individual pressure distribution processing

To compare relative PDT differences between participants, the PDT's were normalised per subject by expressing the PDT as a percentage of the mean of the top 5% PDT of the individual subject. Mean5%MaxPDT was chosen to limit the effect of outliers on the normalisation.

4.2.4. Mean 3D head model

To create the PDT map, a mean head model was made from the 3D scans of all subjects (see Figure 8). The 3D scan of each subject was rigidly aligned with a standard head mesh template in R3DS Wrap 3.4, based on predefined landmarks on the glabella, nose apex, between the alar nasal sulcus-nasolabial sulcus, philtrum, ear lobule and protuberantia occipitalis externa. Next, the mesh template was wrapped on the 3D scan while matching the predefined landmarks (i.e. elastically deform the mesh template to match the shape of the 3D scan), which utilises a variant of the non-rigid iterative closest points algorithm (Dyke et al., 2020). The results were visually checked and interactively adjusted where needed. This process was iterated over all 28 3D scans.

Based on these 28 3D scans, a mean head model was made using a Python script (Huysmans, Goto, Molenbroek, & Goossens, 2020), where all meshes were aligned (Gower, 1975). The mean coordinates were calculated for each vertex (point), from which the mean head mesh was created. The complete process ensures a point-to-point correspondence between the mean model and each 3D scan.

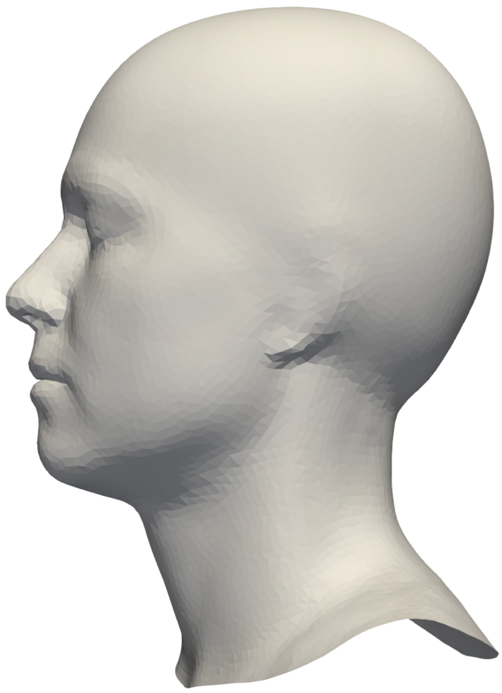

Figure 8 | Mean head model based on 3D scans of all participants (n=28).

The mean 3D head model can be found in '*Smulders (2022) Original PDT_data.zip*'.

4.2.5. Bilaterally symmetric modelling

Using the one-to-one correspondence between the mean model and each participant's 3D scan, landmark locations of each 3D scan were mapped onto the average head model. Note that, due to the manual marker placement, the marker locations can slightly differ between subjects, and thus also end up at slightly different locations of the average head, as shown in Figure 9.

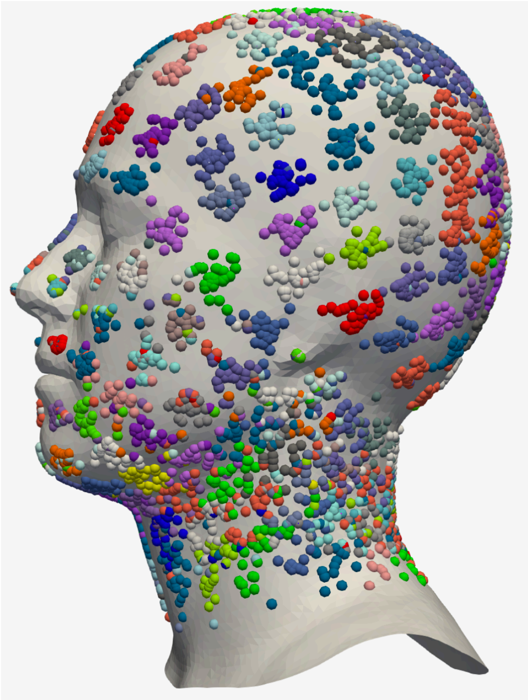

Figure 9 | Landmark locations (n=28). Each colour represents one specific landmark number, showing the proximity of placement of landmarks of all participants. As shown, landmarks form clusters on the head and face, where there is more scattering in the neck. The reason for this is that participants with wider necks had an extra row of landmarks.

Bilateral symmetry was accomplished by utilizing a left-right correspondence on the average head, which was obtained by wrapping a left-right mirrored version of the average head to the original average head. By averaging the vertex coordinates of two head models, an average and symmetric head model was obtained.

In creating the symmetric average model, clipping of the surface to a region of interest (ROI) was needed. To this end the ROI was limited to those parts of the model where for 90% of the subjects there was at least 1 marker within a 30 mm range.

The full dataset can be found in '*Smulders (2022) Original PDT_data.zip*'.

4.2.6. 3D pressure discomfort threshold map

PDT values between markers were obtained from a smooth interpolation of the values at landmark locations to the rest of the average head model, by solving for a solution with a vanishing Laplacian at all vertices (method B from Oostendorp, van Oosterom, and Huiskamp (1989)) (see Figure 10). The resulting symmetric PDT maps, defined on the symmetric average head model, allowed to calculate summary statistics of PDT over the full set of subjects or for gender-specific sub-groups. The same approach was used to create maps of normalised PDT values (Mean5%MaxPDT).

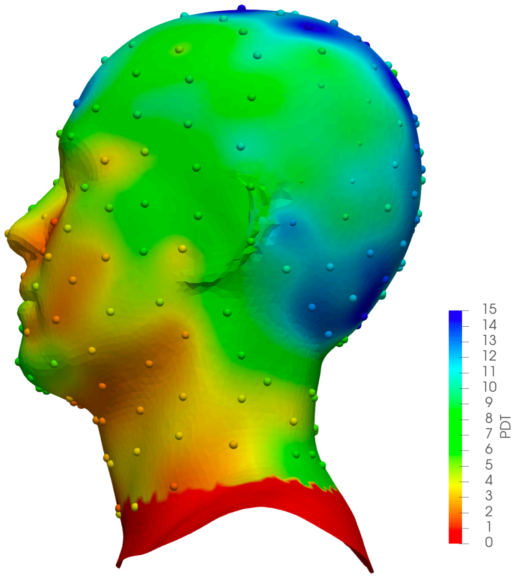

Figure 10 | Actual PDT values (by colour of landmark) and positions of landmarks, with the interpolated PDT on the mean 3D head model in Newtons of one participant (n=1). Please note that shading is on to improve depth perception, which may affect colour (and thus PDT value) interpretation.

The full dataset can be found in '*Smulders (2022) TUDELFT PDT_Mean_nonNorm.vtk*' and '*Smulders (2022) TUDELFT PDT_Mean_Norm.vtk*'.

To aid designers and engineers e.g. in CAD, the average PDT was also mapped to a statistical shape model (SSM) of the human head developed on the CAESAR 3D Anthropometric Database (Robinette, Blackwell, Daanen, Boehmer, & Fleming, 2002) (see Figure 10). While the PDT on different geometric heads is available, it is an approximation using the mean PDT data (n=28) and may not be as representative for the respective populations they are mapped upon.

The full dataset can be found in '*Smulders (2022) CAESAR PDT_Mean_nonNorm.vtk*' and '*Smulders (2022) CAESAR PDT_Mean_Norm.vtk*'.

4.2.7. Statistical analysis

Where previous studies like Shah and Luximon (2021) statistically analyse individual landmarks, this study uses a method with anatomical independent landmarking in order to achieve greater landmark density. This method however does not allow for landmark based analysis, as placed landmarks do not always correspond between participants within this study and previous studies. Therefore, zones are drawn to conduct statistical analysis and compare results with previous studies. Zones scalp, forehead, temple, back head, nose, cheekbone, cheek, mouth, jaw-chin, neck front, and neck back are based on zones of potential interest for different wearables, anatomical features, underlying tissue, landmark locations and observed PDT transitions (see Figure 11).

A Mann-Whitney-Wilcoxon test (two-tailed) was used for comparing gender differences and a Kruskal-Wallis test for identifying difference in median PDT across zones ($p<.05$). A Dunn's Post-hoc (pairwise) tests was used to identify differences per combination of zones, which was compensated for multiple comparisons by controlling False Discovery Rate through the Benjamini-Hochberg procedure. Analysis of gender difference was conducted based on both absolute- and normalised PDT data (Mean5%MaxPDT). All other statistical analysis were conducted based on absolute PDT values only (thus no interpolated nor mirrored data were used).

Statistical analysis results can be found in '*Smulders, M., van Dijk, L.N.M., Song, Y., Vink, P. and Huysmans, T. (2022) Dense 3D pressure discomfort threshold (PDT) map of the human head, face*

and neck: a new method for mapping human sensitivity. Applied Ergonomics, 107 (103919).
https://doi.org/10.1016/j.apergo.2022.103919

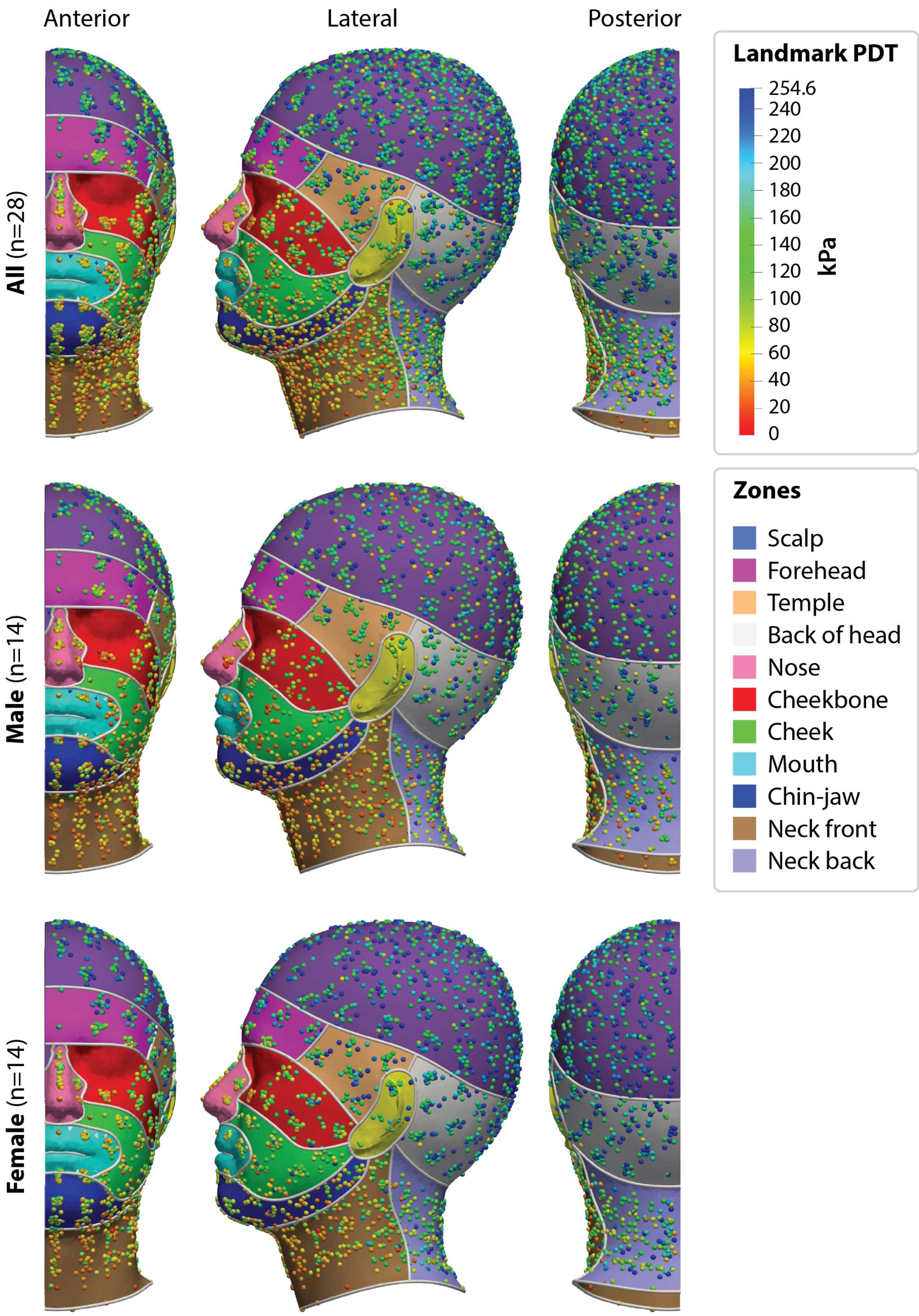

Figure 11 | PDT values in kPa per landmark within zones of all participants (n=28), males (n=14) and females (n=14), anterior, lateral and posterior view. Please note that shading is on to improve depth perception, which may affect colour (and thus PDT value) interpretation.

4.3. Instrument- or software-specific information needed to interpret the data

4.3.1. Reading *.vtk

We recommend to open the *.vtk files in *ParaView* (see Table 4), a free and opensource post-processing visualization engine software. For instructions on how to view the models in *ParaView*, please see the *ParaView* manual (docs.paraview.org).

*Table 4 | Software suggested to read and visualise *.vtk*

Software	Platform	License	Website
ParaView	Unix/Linux, macOS, MS Windows	Free (3BSD)	www.paraview.org

3BSD: 3-clause BSD

4.3.2. Reading *.obj

The *.obj files can be opened in most CAD software (Table 5). Many of these CAD programs support the included PDT map texture, allowing to use the models as a reference in CAD designing products interfacing with the human head, face and/or neck. Free and open-source alternatives to view and edit the *.obj can be found in Table 5, although these software are not intended for CAD.

For a comprehensive list of 3D modelling software, see e.g. https://en.wikipedia.org/wiki/List_of_3D_modeling_software.

*Table 5 | Software suggested to read *.obj*

Software	Platform	License	Website	Suggested Use
Fusion 360	macOS, MS Windows	Commercial (PCS)	www.autodesk.com/products/fusion-360	Viewer, CAD
Rhinoceros	macOS, MS Windows	Commercial (PCS	www.rhino3d.com	Viewer, CAD
SolidWorks	MS Windows	Commercial (PCS)	www.solidworks.com	Viewer, CAD
Inventor	MS Windows	Commercial (PCS)	www.autodesk.com/products/inventor	Viewer, CAD
CATIA	MS Windows	Commercial (PCS)	www.3ds.com/products-services/catia	CAD
Preview	macOS	Free (PCS)	www.apple.com/macos	Viewer
3D Viewer	MS Windows	Free (PCS)	www.apps.microsoft.com/store/detail/3d-viewer/9NBLGGH42THS	Viewer
ParaView	Unix/Linux, macOS, MS Windows	Free (3BSD)	www.paraview.org	Viewer, Editor
MeshLab	Linux, macOS, MS Windows	Free (GPL)	www.meshlab.net	Viewer, Editor
Blender	Linux, macOS, MS Windows	Free (GPL)	www.blender.org	Viewer, Editor
Meshmixer	MS Windows	Free (PCS)	www.meshmixer.com	Viewer, Editor

PCS: Proprietary commercial software
3BSD: 3-clause BSD
GPL: GNU General Public License

Please note that all *nonNormalised* maps are expressed in *PDT* (pressure discomfort threshold), where the *Normalised* maps are expressed as *% of Mean 5% Max PDT*. The *nonNormalised_mean* maps are ranged from 0-20 N or 0-254.6 kPa and the *SD* maps between 0-10 N or 0-127.3 kPa, where the *Normalised_mean* maps range from 0-100% and the *SD* maps between 0-40% (see Figure 12 for a legenda for colour interpretation or the journal publication).

Please note that values of Normalised may exceed 100% in certain individuals.

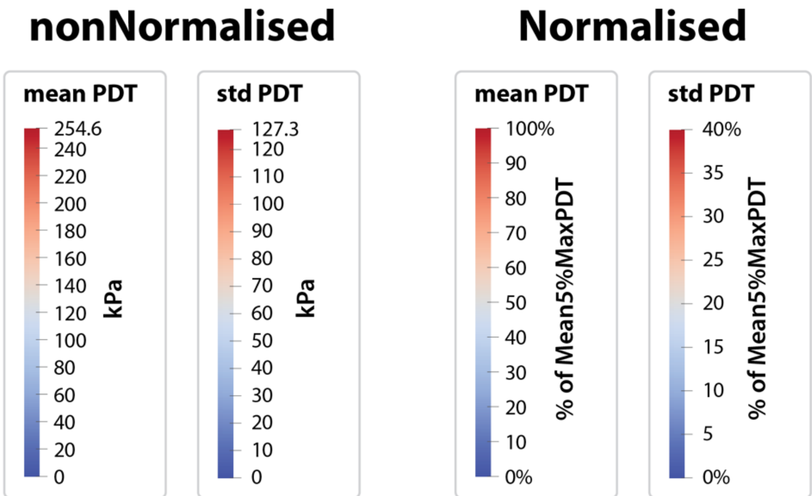

*Figure 12 | Legenda for *.obj color interpretation. Please see also Smulders et al. (2022) Dense 3D pressure discomfort threshold (PDT) map of the human head, face and neck.*

4.3.3. Standards and calibration information

All instruments were factory calibrated.
File standards are shown in Table 6.

Table 6 | File standards used

File type	Standard
*.csv	RFC 4180
*.obj	*Wavefront obj format*
*.pdf	ISO 32000-2
*.vtk	ASCII / *Kitware VTK File Format*

4.3.4. Use of Eigenmodes to create principal component head models

The models *Smulders (2022) CAESAR PDT_Mean_nonNorm.vtk* and *Smulders (2022) CAESAR PDT_Mean_Norm.vtk* contain the PDT maps superimposed on the average head shape derived from the CAESAR database (Robinette et al., 2002). In addition to this, the individual principal components (shape modes) are also included. This allows one to create virtually any plausible head shape as a combination of the average head shape and a weighted combination of the shape modes.

The principal components are embedded in the models as vector fields over the mesh vertices. The vectors are scaled so that a weight of -1 or +1 corresponds to an offset of -3 or +3 standard deviations along that principal component. The software ParaView allows one to easily create such a custom head shape from the model (see Table 7). Please note that the PC range is limited to 1-50.

Table 7 | Software needed to create principal component head models with Eigenmodes

Software	Platform	License	Website
ParaView	Unix/Linux, macOS, MS Windows	Free (3BSD)	www.paraview.org

Step 1 | Select model and set PDT map

Follow the following steps in Figure 13:

1. Open the '*Smulders (2022) CAESAR* *' *.vtk files in ParaView.
2. Press the eye icon [1] to activate one of the *.vtk models.
3. Select the *coloring* [2] layer you want to activate [3], e.g. *PDT_all_mean*.
4. Make sure the *Range* [4] is set correctly (see Table 10) in the field [5] and press [6].

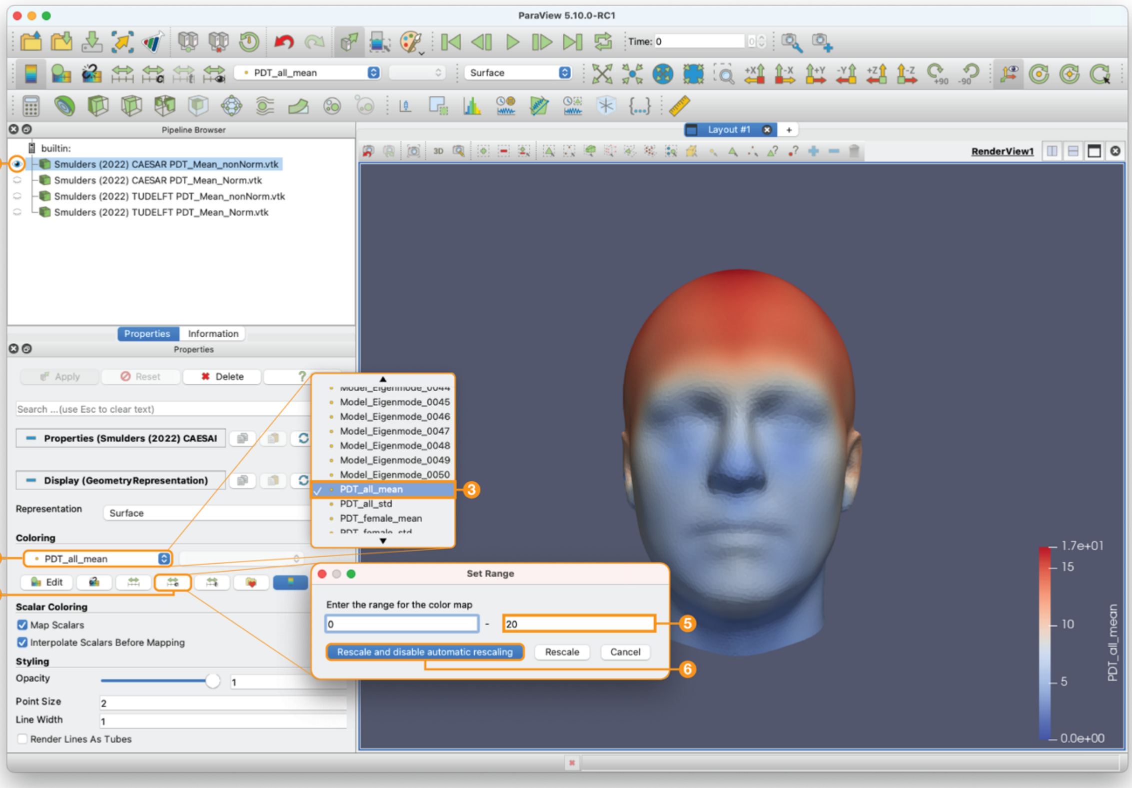

Figure 13 | Select model and prepare for export (ParaView)

Table 8 | Recommended ParaView range settings for PDT maps

Dataset	Normalisation	Map type	Range
CAESAR	nonNorm	mean	0-20 [N]
		std	0-10 [N]
	Norm	mean	0-100 [%][1]
		std	0-40 [%]
TUDELFT	nonNorm	mean	0-20 [N]
		std	0-10 [N]
	Norm	mean	0-100 [%][1]
		std	0-40 [%]

[1]Data may exceed 100% in certain individuals.

Step 2 | Apply 'Warp By Vector' filter

Follow the following steps in Figure 14:

5. Press *Filters* > *Search…* [7] (or press Mac: ⌥ + Spacebar | Windows: Alt + Spacebar)
6. Type "*warp by vector*" to search [8], press *Enter* to select the *Warp By Vector* filter [9] (use keys to navigate up or down in selection list, press Enter to select, press *Esc* to exit search).
7. The *Warp By Vector* filter of *Model_Eigenmode_0001* with weight factor 1.0 (+3σ) is automatically applied.

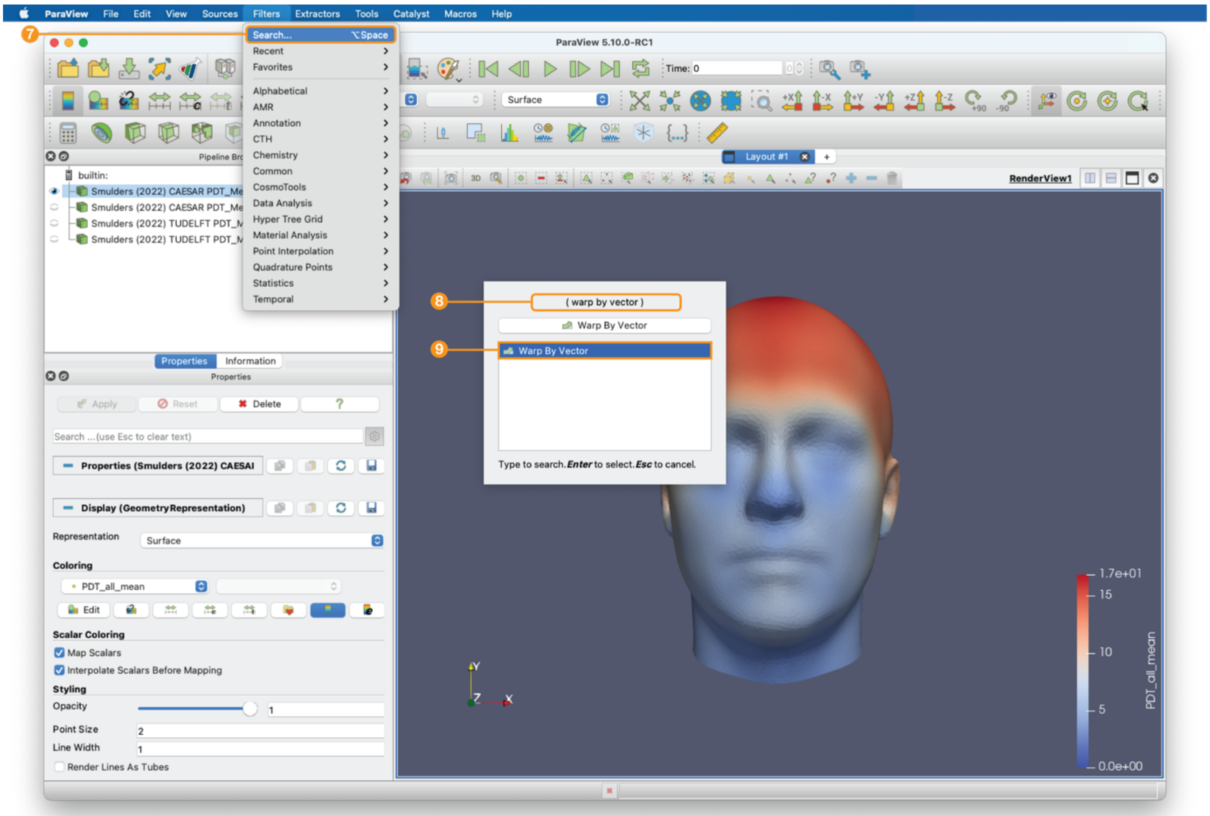

Figure 14 | Apply 'Warp By Vector' filter to create Eigenmode model (ParaView)

Step 2 | Change and apply shape modes

Follow the following steps in Figure 15:

8. The weight factor of *Model_Eigenmode_0001* can be changed in field *Scale Factor* [10] between -1.0 (-3σ) and 1.0 (+3σ). 0 results in no vector applied.
9. The desired shape mode can be changed in drop-down menu *Vectors* [11], showing all *Model_Eigenmode_0001-0050*. Click on the *Model_Eigenmode_** to apply [12].

   Please note that evetime one *Model_Eigenmode_** is selected, it is automatically applied with weight factor 1.0 (+3σ). This can be changed in *Scale Factor* [10]. Multuple *Model_Eigenmode_** can be applied to create the desired model.

10. The *coloring* [13] and *Range* [14] can be still adjusted if needed within *WrapByVector1*.

To export the created Eigenmode PDT map, see §4.3.5 step 2-4.

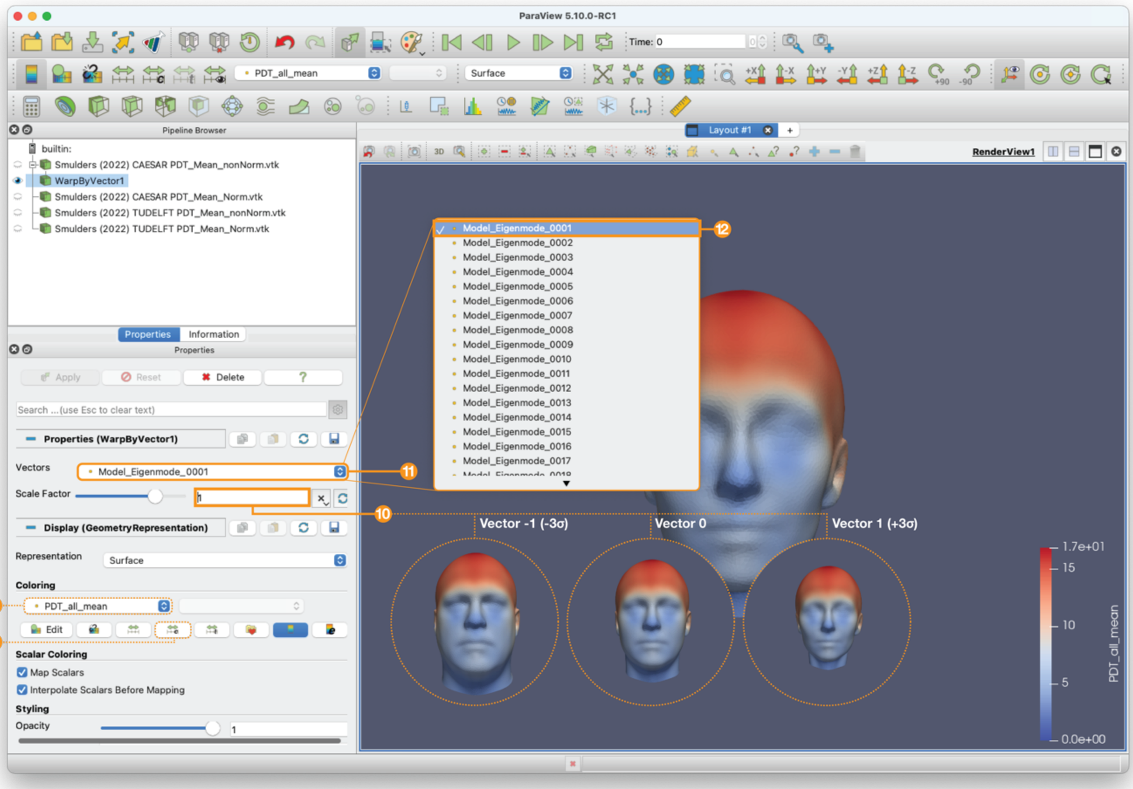

Figure 15 | Change the 'Warp By Vector' filter to customise Eigenmode model (ParaView)

4.3.5. Make *obj's from ParaView for CAD with MeshLab

Unfortunately, ParaView (v5.10.0) cannot export *.obj with textures. But with a detour via MeshLab you can create *.obj files with textures of ParaView *.vtk models. Please see Table 9 for software needed.

*Table 9 | Software needed to create *.obj's from *.vtk's*

Software	Platform	License	Website
ParaView	Unix/Linux, macOS, MS Windows	Free (3BSD)	www.paraview.org
MeshLab	Linux, macOS, MS Windows	Free (GPL)	www.meshlab.net

Step 1 | Select model and set PDT map

Follow the following steps in Figure 16:

1. Open the *.vtk files in ParaView.
2. Press the eye icon [1] to activate one of the *.vtk models.
3. Select the *coloring* [2] layer you want to activate [3], e.g. *PDT_all_mean*.
4. Make sure the *Range* [4] is set correctly (see Table 10) in the field [5] and press [6].

Table 10 | Recommended ParaView range settings for PDT maps

Dataset	Normalisation	Map type	Range
CAESAR	nonNorm	mean	0-20 [N]
		std	0-10 [N]
	Norm	mean	0-100 [%][1]
		std	0-40 [%]
TUDELFT	nonNorm	mean	0-20 [N]
		std	0-10 [N]
	Norm	mean	0-100 [%][1]
		std	0-40 [%]

[1]Data may exceed 100% in certain individuals.

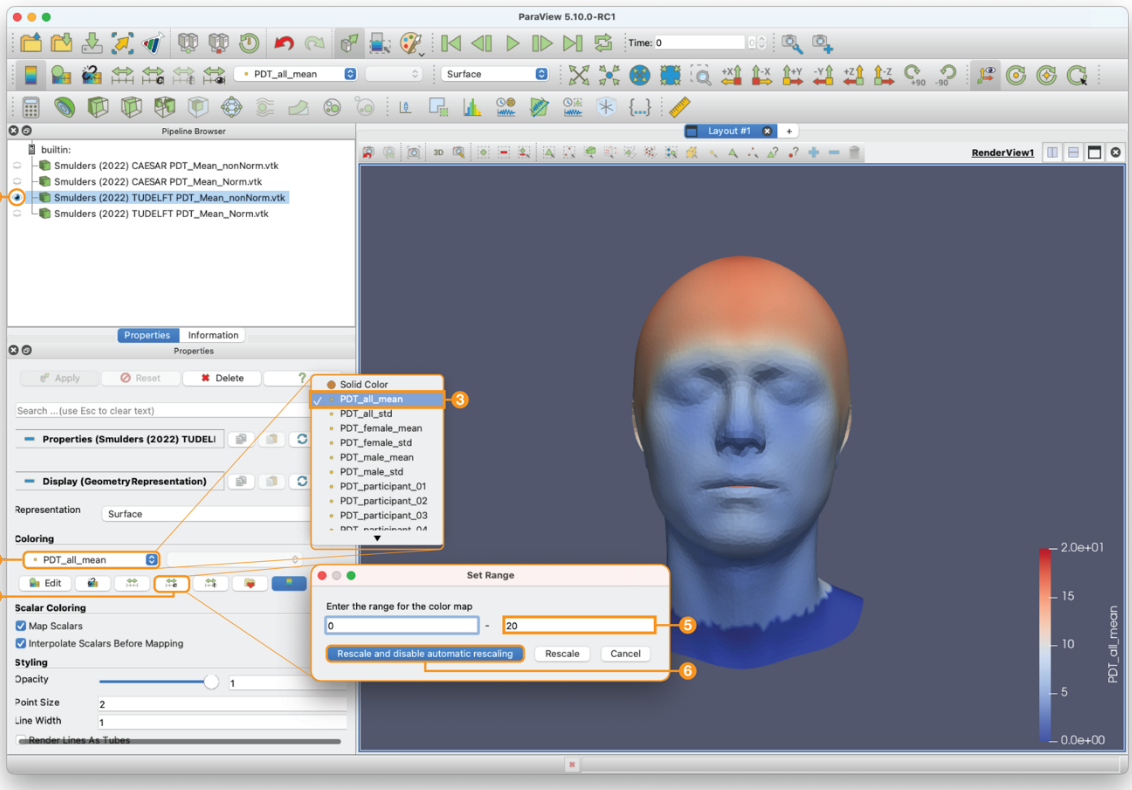

Figure 16 | Select model and prepare for export (ParaView)

*Step 2 | Save model as *.ply*

Follow the following steps in Figure 17 and Figure 18:

11. Press *File* > *Save Data…* [7] (or press Mac: ⌘ + S | Windows: Crtl + S)
12. Select the correct output folder where you want to save your files [8]
13. Create a logical name for your export file [9]
14. Click on *file type* [10] and select *PLY Polygonal File Formal (*.ply)* [11]
15. Click *OK* [12] (or press *Enter*)
16. In the new window, under *Color options* select *Enable Coloring* [13]
17. Click *OK* [14] (or press *Enter*)

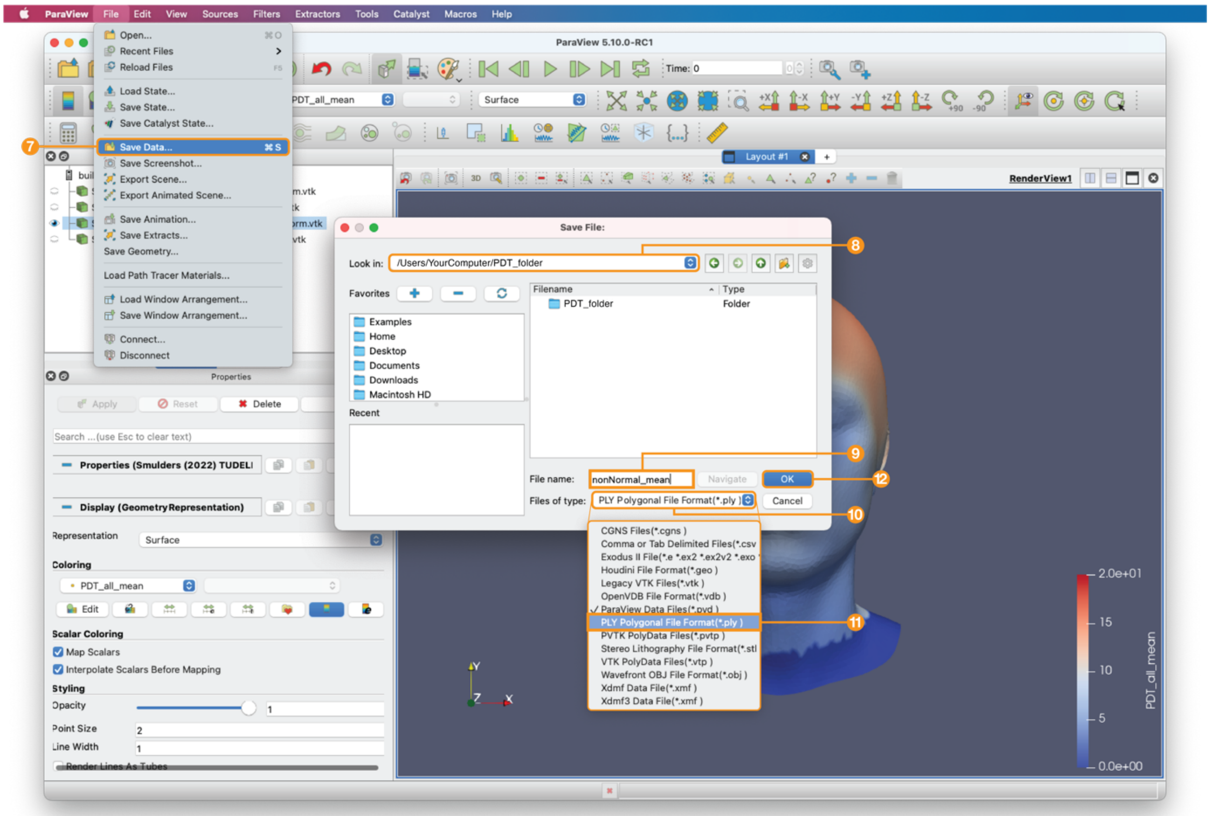

*Figure 17 | Save model as *.ply (ParaView)*

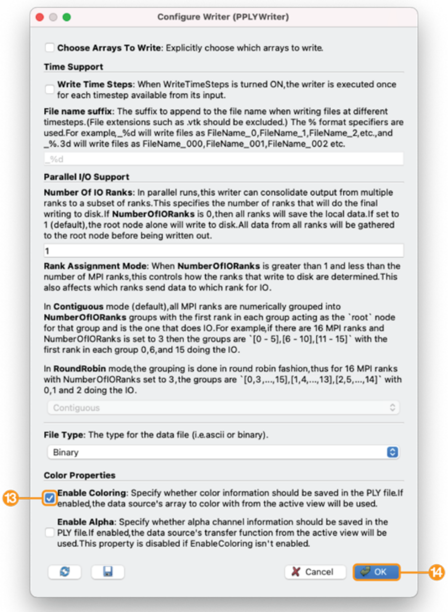

*Figure 18 | Save model as *.ply and Enable Coloring (ParaView)*

*Step 3 | Open *.ply model*

Follow the following steps in Figure 19:

18. Start MeshLab.
19. Press *File* > *Import Mesh...* [15] (or press Mac: ⌘ + I | Windows: Crtl + I)
20. Select the correct *.ply file [16]
21. Open the file by clicking *Open* [17] (or press Enter)

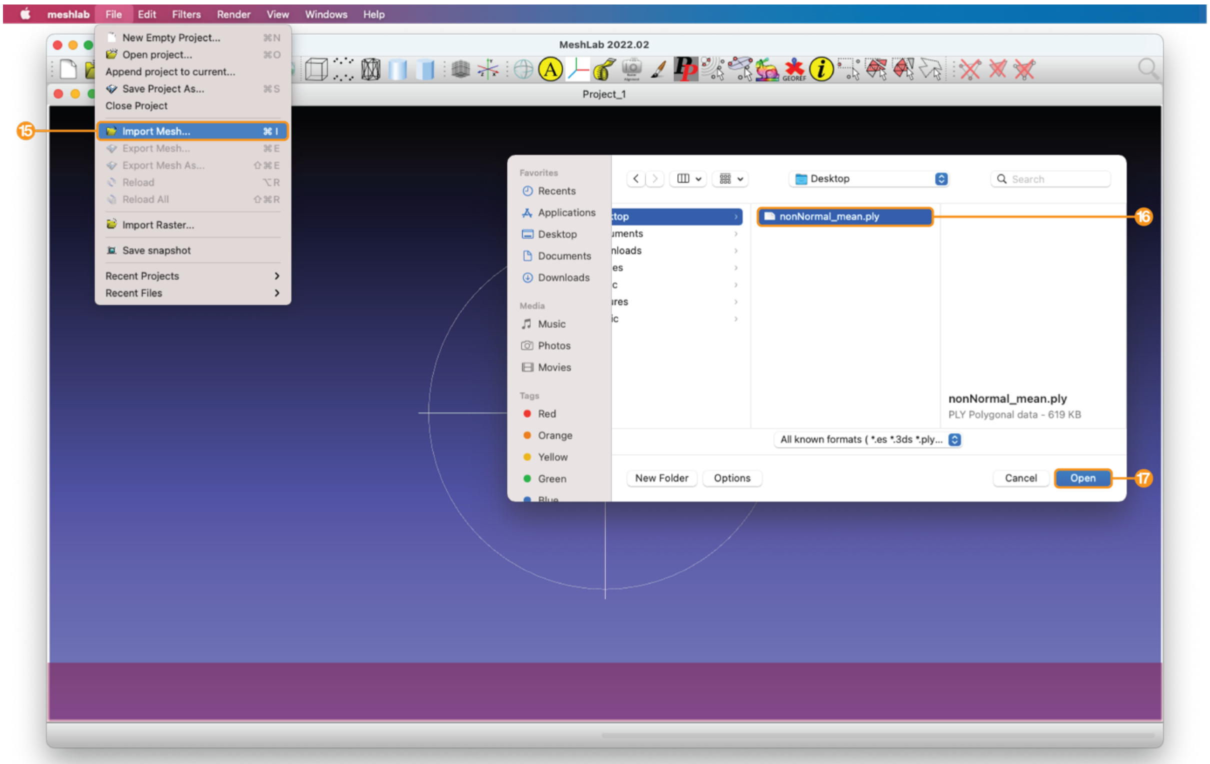

Figure 19 | Open .PLY model (MeshLab)

*Step 4 | Save model as *.obj*

Follow the following steps in Figure 20 & Figure 21:

22. Press *File* > *Export Mesh As...* [18] (or press Mac: ⇧ + ⌘ + E | Windows: Crtl + Shift + E)
23. Click file format [19]
24. Select *Alias Wavefront Object (*.obj)* [20]
25. Click *Save* (or press Enter) [21]
26. Click *OK* (or press Enter) [22]

You now have an *.obj file of the selected *.vtk model, which can be used in e.g. CAD as an underlayer for designing products that interface with the human head, face and neck.

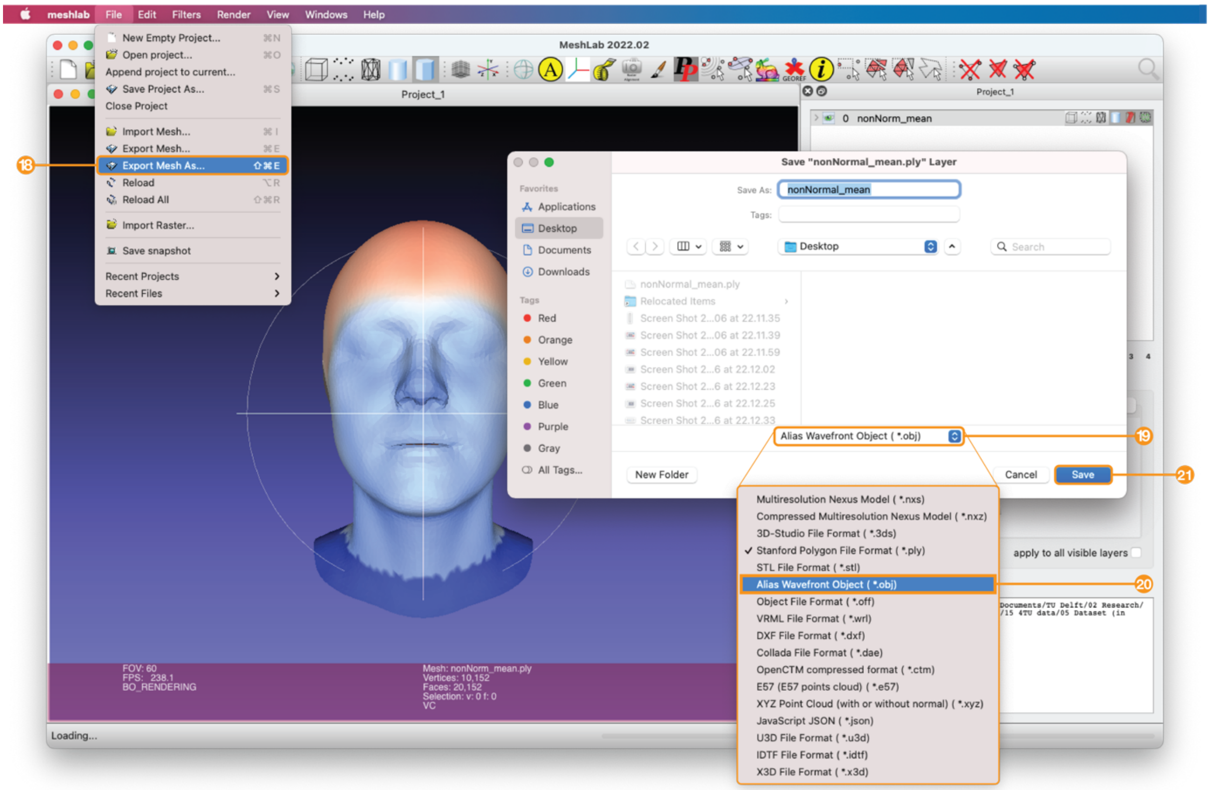

*Figure 20 | Save model as *.obj (MeshLab)*

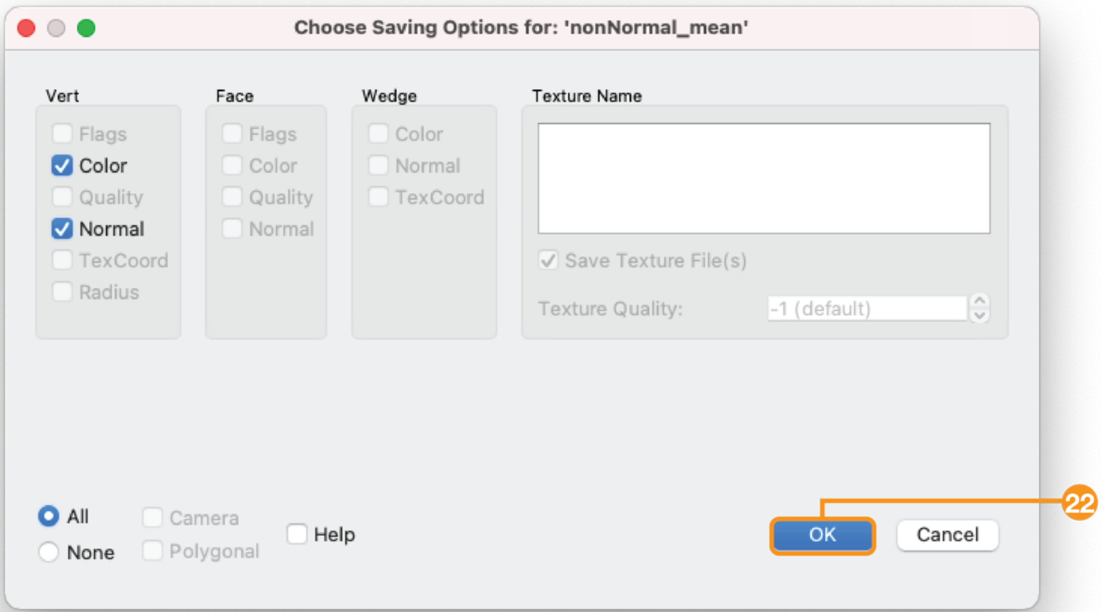

*Figure 21 | Save model as *.obj with Color and Normals (MeshLab)*

4.4. Experimental conditions

Data is collected in a controlled lab environment (room temperature) at the Faculty of Industrial Design Engineering, Delft University of Technology.

4.5. Describe any quality-assurance procedures performed on the data

Visual inspections of models in Artec Studio, R3DS Wrap and ParaView.
Backup photographs of landmark placement for landmark identification.
PDT values visually inspected and checked with control (average) values in Excel.
Use of high-quality 3D scanner and pressure gauge.

4.6. People involved with sample collection, processing, analysis and/or submission

Lead Author/Lead Investigator/Data analyst
Name: Maxim Smulders
ORCID: 0000-0001-9957-0991
Institution: Faculty of Industrial Design Engineering
Delft University of Technology
Address: Landbergstraat 15
2628CE Delft
The Netherlands
Email: m.smulders@tudelft.nl

Author/Investigator
Name: Lisanne N.M. van Dijk
ORCID: 0000-0002-8626-7296
Institution: Crescent Medical B.V.
Address: Vlamingstraat 72A
2611KZ Delft
The Netherlands

Author/Investigator/Data analyst
Name: Yu (Wolf) Song
ORCID: 0000-0002-9542-1312
Institution: Faculty of Industrial Design Engineering
Delft University of Technology
Address: Landbergstraat 15
2628CE Delft
The Netherlands
Email: y.song@tudelft.nl

Author/Investigator
Name: Peter Vink
ORCID: 0000-0001-9985-3369
Institution: Faculty of Industrial Design Engineering
Delft University of Technology
Address: Landbergstraat 15
2628CE Delft
The Netherlands
Email: p.vink@tudelft.nl

Author/Principal Investigator/Lead data analyst
Name: Toon Huysmans
ORCID: 0000-0001-7053-6458
Institution[1]: Faculty of Industrial Design Engineering
Delft University of Technology
Address[1]: Landbergstraat 15
2628CE Delft
The Netherlands
Email[1]: t.huysmans@tudelft.nl

Institution[2]: Imec-Vision Lab
Department of Physics
University of Antwerp
Address[2]: Universiteitsplein 1
B-2610 Antwerp
Belgium

Lab manager
Name: B.J. Naagen
Institution: Faculty of Industrial Design Engineering
Delft University of Technology
Address: Landbergstraat 15
2628CE Delft
The Netherlands
Email: b.j.naagen@tudelft.nl

Lab assistant (guest)
Name: Liliana Di Brigida
ORCID: 0000-0002-6324-2678
Institution: Dipartimento di Ingegneria Industriale
University of Salerno
Address: Via Giovanni Paolo II 132
84084 Fisciano SA
Italy

5. DATA-SPECIFIC INFORMATION

Below all data-specific information is given. Please note that datasets (e.g. *.vtk and *.csv) can be combined when they contain data with similar variables and cases/rows, but saved in different file formats. Please see §4.3 for recommended software to open the files.

Smulders (2022) TUDELFT PDT_Mean_nonNorm.vtk[1] Smulders (2022) TUDELFT PDT_Mean_nonNorm.csv Smulders (2022) TUDELFT PDT_Mean_Norm.vtk[1] Smulders (2022) TUDELFT PDT_Mean_Norm.csv		
Number of variables:	38	
Number of cases/rows:	10153	
Variable List: *Range between 01-29	Variable	Explanation
	PDT_participant_*	PDT values of individual participant in Newtons
	PDT_all_mean	Mean PDT values of all participants (n=28) in Newtons
	PDT_all_std	Standard deviation of PDT values of all participants (n=28) in Newtons
	PDT_male_mean	Mean PDT values of all male participants (n=14) in Newtons
	PDT_male_std	Standard deviation of PDT values of all male participants (n=14) in Newtons
	PDT_female_mean	Mean PDT values of all female participants (n=14) in Newtons
	PDT_female_std	Standard deviation of PDT values of all female participants (n=14) in Newtons
	valid_points	All points that are within ROI (see §4.2.5)
	Points:0	X-coordinate of point
	Points:1	Y-coordinate of point
	Points:2	Z-coordinate of point
Missing data codes:	0	
Specialised formats or other abbreviations used:	n.a.	

[1] The *.vtk structure description can be found in *§19.3 VTK File Formats* of the *The VTK User's Guide* 11th Edition (see https://www.kitware.com/products/books/VTKUsersGuide.pdf).

Smulders (2022) CAESAR PDT_Mean_nonNorm.vtk[1] Smulders (2022) CAESAR PDT_Mean_nonNorm.csv Smulders (2022) CAESAR PDT_Mean_Norm.vtk[1] Smulders (2022) CAESAR PDT_Mean_Norm.csv		
Number of variables:	188	
Number of cases/rows:	15118	
Variable List:	**Variable**	**Explanation**
* Range between 0001-0050 ** Range between 01-29	Model_Eigenmode_*:0	X-value of vector
	Model_Eigenmode_*:1	Y-value of vector
	Model_Eigenmode_*:2	Z-value of vector
	PDT_participant_**	PDT values of individual participant in Newtons
	PDT_all_mean	Mean PDT values of all participants (n=28) in Newtons
	PDT_all_std	Standard deviation of PDT values of all participants (n=28) in Newtons
	PDT_male_mean	Mean PDT values of all male participants (n=14) in Newtons
	PDT_male_std	Standard deviation of PDT values of all male participants (n=14) in Newtons
	PDT_female_mean	Mean PDT values of all female participants (n=14) in Newtons
	PDT_female_std	Standard deviation of PDT values of all female participants (n=14) in Newtons
	valid_points	All points that are within ROI (see §4.2.5)
	Points:0	X-coordinate of point
	Points:1	Y-coordinate of point
	Points:2	Z-coordinate of point
Missing data codes:	0	
Specialised formats or other abbreviations used:	n.a.	

[1] The *.vtk structure description can be found in §*19.3 VTK File Formats* of the *The VTK User's Guide* 11th Edition by Kitware and Sandia National Laboratories (see https://www.kitware.com/products/books/VTKUsersGuide.pdf).

Smulders (2022) Participant_characteristics.csv		
Number of variables:	6	
Number of cases/rows:	28	
Variable List:	**Variable**	**Explanation**
	Participant ID	Unique participant number
	Gender [M/F/X]	Gender, as described as Male / Female / X (Non-binary or not given)
	Ethnicity	Ethnical heritage from parents, expressed as nationality.
	Age [y]	Age in years
	Height [cm]	Stature height in centimetres
	Weight [kg]	Weight in kilograms
Missing data codes:	0	
Specialised formats or other abbreviations used:	**Abbreviation**	**Meaning**
	M/F/X	Gender Male / Female / X (Non-binary or not given)
	y	years (based on date of birth and date of test)
	cm	centimetre (SI unit)
	kg	kilogram (SI unit)

Smulders (2022) Original PDT_data.zip[1,2]		
Number of variables:		
Number of cases/rows:		
Variable List: * Range between 01-29	**Variable**	**Explanation**
	Original_Head	Average head model based on 3D geometry of all participants (n=28) from study Smulders et al. (2022)
	Original_PDT_participant_*	Point 3D coordinates with corresponding PDT values of individual participant from study Smulders et al. (2022)
Missing data codes:	0	
Specialised formats or other abbreviations used:	.obj .vtk	

[1] The *.vtk structure description can be found in §*19.3 VTK File Formats* of the *The VTK User's Guide* 11th Edition by Kitware and Sandia National Laboratories (see https://www.kitware.com/products/books/VTKUsersGuide.pdf).

[2] The *.obj structure description can be found in *Appendix B1. Object Files (.obj)* of the *Advanced Visualizer Manual* by Wavefront Technologies (since 2006 part of Autodesk) (see http://fegemo.github.io/cefet-cg/attachments/obj-spec.pdf). For more details, see also *Wavefront OBJ File Format* by the Library of Congress Collections, USA (see https://www.loc.gov/preservation/digital/formats/fdd/fdd000507.shtml).

<table>
<tr><th colspan="3">Smulders (2022) OBJ PDT_maps.zip[2]</th></tr>
<tr><td>Number of variables:</td><td colspan="2">1</td></tr>
<tr><td>Number of cases/rows:</td><td colspan="2">24</td></tr>
<tr><td rowspan="11">Variable List:</td><td>Variable</td><td>Explanation</td></tr>
<tr><td>CAESAR</td><td>Models based on 3D geometry from CAESAR database by Robinette et al. (2002)</td></tr>
<tr><td>TUDELFT</td><td>Models based on 3D geometry from study Smulders et al. (2022)</td></tr>
<tr><td>nonNorm</td><td>non-normalised</td></tr>
<tr><td>Norm</td><td>normalised</td></tr>
<tr><td>PDT_all_mean</td><td>Mean PDT values of all participants (n=28) in Newtons</td></tr>
<tr><td>PDT_all_std</td><td>Standard deviation of PDT values of all participants (n=28) in Newtons</td></tr>
<tr><td>PDT_male_mean</td><td>Mean PDT values of all male participants (n=14) in Newtons</td></tr>
<tr><td>PDT_male_std</td><td>Standard deviation of PDT values of all male participants (n=14) in Newtons</td></tr>
<tr><td>PDT_female_mean</td><td>Mean PDT values of all female participants (n=14) in Newtons</td></tr>
<tr><td>PDT_female_std</td><td>Standard deviation of PDT values of all female participants (n=14) in Newtons</td></tr>
<tr><td>Missing data codes:</td><td colspan="2">0</td></tr>
<tr><td>Specialised formats or other abbreviations used:</td><td colspan="2">.obj</td></tr>
</table>

[2] The *.obj structure description can be found in *Appendix B1. Object Files (.obj)* of the *Advanced Visualizer Manual* by Wavefront Technologies (since 2006 part of Autodesk) (see http://fegemo.github.io/cefet-cg/attachments/obj-spec.pdf). For more details, see also *Wavefront OBJ File Format* by the Library of Congress Collections, USA (see https://www.loc.gov/preservation/digital/formats/fdd/fdd000507.shtml).