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Design Optimisation for efficient electric vehicles based on a User-centric approach

DOMUS – Deliverable Report

D1.3 Holistic Passenger Comfort Model for Vehicles

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Change Log

Version	Modifications of document	Author	Date
1.0	Creation of the document: table of content, section pre-assigned to partners, raw input in some sections (experimentation package, grant agreement, email exchanges)	Alexandre Gentner	2019/03/27
1.1	- Content added for “6.5 TME experimentations”- Questionnaire A to C added as appendix	Giuliano Gradinati, Alexandre Gentner	2019/04/19
1.2	Content added in “7. Mathematical Modelling” (preliminary version of the model)	Kojo Sarfo Gyamfi	2019/04/30
1.3	TME inputs in section “5. Experimentation planning”: - Writing of 5.1 General guidelines - Description of assigned factors (5.2) - Description of assigned questionnaires (5.3) - Writing of protocol section (5.4) Document formatting (creation of caption of figures, tables..), structuring of section 3…	Giuliano Gradinati, Alexandre Gentner	2019/05/15
1.4	Content added in “6.3 CRF experiments”	Fabrizio Mattiello, Francesca Bandera, Alberto Maria Merlo	2019/05/21
1.5	- ViF inputs in section “5. Experimentation planning”: - Description of assigned factors (5.2) - Description of assigned questionnaires (5.3) - Content (partial) added in “6.6 ViF experiments”	Peter Moertl, Margit Höfler, Benjamin Ewerz	2019/07/31
1.6	Content added in “6.2 COV experiments”	Kojo Sarfo Gyamfi, James Brady,	2019/09/06
	- Addition of 4.5 Holistic comfort from a psychological perspective - High level structure of section 5 adjusted. All experimentations are introduced in 5.1 from a big picture perspective and following sub-sections describe “comfort factors”, “environmental factors”, “individual factors”, “dependant measures” and “protocol”	Alexandre Gentner, Peter Moertl	
1.7	Update of table of content (wording of sections + “Relevant findings” and “discussion” sub-sections added to each partner experimentations) following teleco discussion of 12/09/2019	Alexandre Gentner	2019/09/12
1.8	IDIADA reviewing comments	Guillem Badia	2019/09/23
	Improved flow in “6.4 TME study” + addition of “6.4.6 Relevant findings” + “6.4.7 Discussions”	Alexandre Gentner	
	- Adjustment of holistic comfort model figure - Addition/adjustment of sections regarding sound and task in 5.2 and 5.3 - Improved flow in “6.5 ViF study” now also including “6.5.3 Relevant findings and Discussions”	Peter Moertl	
	- input in section 5 (5.3.2, 5.3.4, 5.4.5, intro of 5.5) - Writing of “6.3 ika study”	Fabian Prinz, Gudrun Voß, Stefan Ladwig	

Version	Modifications of document	Author	Date
1.9	- Input in section 4.1, 4.2, 4.3 - Overall consistency check (spelling, cross-references…)	Alexandre Gentner	2019/09/25
1.10	- Publishable summary added (except for result section)	Alexandre Gentner	2019/09/27
1.11	- Input to sections 4.6, 4.7, 5.2.8, 7 - Text revisions and comments	Kojo Sarfo Gyamfi, James Brusey	2019/10/03
	Sections 5.2, 5.3, 6.2.3 and 6.2.4 included	Fabrizio Mattiello, Francesca Bandera, Alberto Maria Merlo, Andrea Zussino	
	- Text revisions	Alexandre Gentner	
1.12	- Revision of section 5.2.1	Fabian Prinz, Thomas Hirn	2019/10/10
2.0 (Full draft)	- Addition of content in sections 7, 8, 9 and 10	Kojo Sarfo Gyamfi, James Brusey	2019/10/14
2.1	- Slight revision of section 6.2.2	Alberto Maria Merlo	2019/10/17
2.2	- Revisions based on review comment (section 4.5)	Peter Moertl	2019/10/22
	- Revisions based on review comment (Publishable summary)	Alexandre Gentner	
2.3	- Overall document revisions (grammar, spelling) - Section 13 (quality assurance)	James Brusey	2019/10/25
2.4	- Slight revision of section 7.1.4	Fabian Prinz	2019/10/28
2.5	- Slight revision of section 5.2 intro - Addition of section 6.1.7 and 6.1.8 - Revision of section 7	Kojo Sarfo Gyamfi, James Brady	2019/11/04
	- Slight overall adjustment of formatting and referencing (figure, table, picture)	Alexandre Gentner	
2.6	Revision of results and conclusions	Kojo Sarfo Gyamfi, James Brusey	2019/12/17
2.7	Revisions based on further review comments for sections 3, 4.1, 6.4, 6.5, 7 & 8	Kojo Sarfo Gyamfi, James Brusey, Peter Moertl, Alexandre Gentner	2020/01/10
2.8	Addition of the paragraph about the “Attainment of the objectives and explanation of deviations” in executive summary following EC review.	James Brusey, Alexandre Gentner	2020/04/07
2.9	Adjustment of deliverable structure with adding of a new chapter 1 dedicated to the attainment of objectives and explanation of deviations	Alexandre Gentner	2020/04/17

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Publishable summary

Background

The aim of this deliverable is to provide a basis for assessing passenger comfort in a holistic model that quantifies comfort and includes based thermal comfort complemented by other factors.
The factors considered have been identified in the list of priority factors influencing comfort identify by literature review and expert inputs in D1.1.

The comfort model developed in this task returns a comfort indicator value. This comfort indicator is used by the assessment framework developed in D1.2. which provides a user-centric assessment of the energy use of a car cabin and climate control system while ensuring it meets expectations for comfort and safety. The mathematical holistic comfort model can also be interpreted from a psychological perspective and thus provide a more intuitive explanation and reasoning about why the various factors (such as, scent or light) have a particular effect on comfort perception.

The comfort model helps define the set of sensors and additional active comfort components and is used in for the definition of user-centred control strategies. The comfort model as part of the assessment framework will then also be used for virtual assessments of technical/technological solutions developed within DOMUS.

Task objectives

The objectives of the sub-task carried out are the following.

Context understanding:
- develop a contextual understanding of holistic comfort from a psychological perspective.

Methods:
- develop overall methods allowing comparability and generalisability and replicability of the data collection over the five study locations
- develop individual study methods allowing to assess influences on holistic comfort of factors identified

Analysis – mathematical modelling:
- only include comfort aspects shown to be significant
- predict subjective comfort significantly more accurately compared with the base comfort model

Methods

All involved partners to the task of defining overall methods through regular teleconference and face to face workshops (activity started as part of T1.1 and preliminary results have been reported in D1.1 and D1.2).

The methods consist of:

- alignment of **contextual understanding** of holistic comfort
- a defined set of **comfort factors** that will be manipulated in at least one of the five study
- **environmental factors** and **individual factors** that have to be treated as independent variables in the studies (including a description of target levels and measurement set-up when relevant)
- a list of **dependent variables** to be collected
- general guidelines regarding the **procedure** to follow in the studies, including questionnaire templates allowing to collect data regarding dependent variables and certain individual factors
- **analysis** of the acquired datasets

Table 1: Factors and dependent variables considered in the overall methods

Comfort factors	Environmental factors	Individual factors	Dependent variables
- radiation wavelength and irradiance - asymmetrical (sun) radiation - air flow - sound - task - ambient scent - ambient light colour	- air temperature - radiation - relative humidity - air velocity - air quality - experimental space and seating type - lighting experimental space - ambient scent	- demographic - clothing - thermal and activity history - metabolic rate - thermal sensibility - acoustic sensibility	- thermal sensation - comfort appreciations - task load

This deliverable also presents detailed individual study methods including description of the study designs, tasks, apparatus, stimuli, set-up and procedure.

Results

The key results include:

1. The DOMUS consortium collected and summarised experimental datasets from each of the 5 involved partners, involving a total of 149 participants over an elapsed duration of 242 hours (see details in Table 2).

Table 2: Overview of experimental work in terms of participants and duration

	Participants	**Duration per participant**	**Total duration**	
	(#)	*(minutes)*	*(minutes)*	*(hours)*
COV	10	30	300	5.0
CRF	31	40	1240	20.7
IKA	29	240	6960	116.0
TME	47	60	2820	47.0
VIF	32	100	3200	53.3
DOMUS studies	**149**	**470**	**14520**	**242.0**

2. We produced comparative results for a series of models and a variety of sub-selections of the experimental datasets. The full aggregated dataset produces a binary comfort classifier with Logistic Regression that is accurate 78% of the time.
3. In comparison, the baseline thermal comfort model was only able to correctly predict comfort 58% of the time for the same dataset.
4. This deliverable provides the model parameters and associated equations for the best performing model.

These results meet the requirements set out in the objectives for this part of the project and provide a strong foundation for the remainder of the DOMUS work to build upon.