08-020

DISCOMFORT AND USER SATISFACTION DEPENDING ON PRESSURE AND VIBRATION PERCEPTION WHILE USING POWER TOOLS

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Comfort measurement is not a simple task, as multiple factors and aspects related with the subjective perception of users take part in such processes. To address it in an obective way, comfort associated with pressure and vibration is measured during the use of drilling machines. Thus, 60 users tested three different drill models, indicating the level of comfort felt and the number of discomfort locations perceived in the hands and in the rest of the body. Three binary logistic regression models are obtained from the recorded data, considering pressure and vibration related comfort as independent variables, and satisfaction with the experience of use, hand discomfort and discomfort in the rest of the body as dependent variables. The results show that satisfaction of use depends on pressure and vibration related comfort, and, lastly, that discomfort throughout the body is only related to pressure comfort. These models can be useful in improving the ergonomic design of machine tools from the conceptual design phase.

Keywords: user oriented design; comfort; discomfort; user satisfaction

MOLESTIAS Y SATISFACCIÓN DE USUARIO EN FUNCIÓN DE LA PERCEPCIÓN DE PRESIONES Y VIBRACIONES DURANTE EL USO DE MÁQUINAS HERRAMIENTA

La medición del confort no resulta sencilla al tratarse de un fenómeno en que intervienen múltiples factores y aspectos relacionados con la percepción subjetiva del usuario. Para abordarlo de un modo objetivo en este trabajo se mide el confort asociado a presiones y a vibraciones durante el uso de máquinas de taladrar. Así, 60 sujetos probaron tres modelos distintos de taladro, indicando el nivel de confort alcanzado y el número de molestias percibidas en las manos y en el resto del cuerpo. A partir de los datos registrados se obtienen tres modelos de regresión logística binaria con el confort a presiones y vibraciones como variables independientes y con satisfacción con la experiencia de uso, molestias en las manos y molestias en el resto del cuerpo como variables dependientes. Los resultados indican que la satisfacción de uso depende del confort a presiones y vibraciones, las molestias en las manos dependen sólo del confort a vibraciones y, por último, las molestias en todo el cuerpo se relacionan sólo con el confort a presiones. Estos modelos pueden ser de utilidad para mejorar el diseño ergonómico de máquinas herramienta desde las fases de diseño conceptual.

Palabras clave: diseño orientado al usuario; confort; molestias; satisfacción

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1. Introduction

In the context of product design, ergonomics is a fundamental factor to be taken into account to guarantee a correct adaptation of product form, dimensions and operation into a comfortable and non health-risking user experience (Sagot, Gouin, and Gomes, 2003; Artacho Ramírez et al., 2018). To be able to identify the internal and external factors that modulate such a user experience, as well as to identify the domains where effects are most predominant should belong to the objectives of every modern product design methodology.

Classical design methodologies start by considering basic user needs and by defining the different functions the product has to perform. In doing so, they split the product in different subsystems, components and parts. This approach has been losing relevance against other procedures which focus on user-product interaction phenomena and sensations (Kaulio, 1998).

In more modern design methodologies, new starting points have proven to be useful (Filippi and Barattin, 2015; Sonderegger and Sauer, 2010), and shapes and the comfort derived from user-product shapes interactions can be seen as a new starting point. Comfort is considered a key element in the sensation spectrum which surrounds and affects users during product use in different contexts (Yang et al., 2008; Li and Jiang, 2010). Some researchers relate it to physical phenomena taking place in the user-product interface (Kang et al., 2007; Shivpaul, 2017), while others define comfort predicting descriptors (Sharma, Kumar and Das, 2016) trying to rationalise different factors of comfort influence during product use.

This work aims to provide a first insight into power tool comfort modelling. Previous research approaches the study of comfort as a whole, without discerning between different kinds of comfort that could be experienced during product use (Chen, Nigg and de Koning, 1994; Au and Goonetilleke, 2007). While multiple different physical phenomena are studied separately, their effect on a holistic perspective of user comfort is assessed without differentiating between the various types of comfort a user is capable of assesing during product use. For example, Goonetilleke, (1999) focuses on the study of pressure spatial distribution, relating it to a general comfort experience; Chen, Nigg and de Koning, (1994) relate shifts of plantar pressure to shoe comfort; Sharma, Kumar and Das, (2016) identify various factors which determine comfort during product use. However, to the authors knowledge, the analysis of the influence that perceived comfort triggered by different physical inputs have on product experience satisfaction and pain perception, also described in literature as discomfort (Hertzberg, 1972; Slater, 1985; Zhang, Helander and Drury, 1996; Helander, 2003; Kuijt-Evers et al., 2005), has not been addressed in the literature. Thus, the starting hypothesis in this study is that users' satisfaction and pain (or discomfort) could depend, to a different extent, on different kinds of perceiving comfort related to different physical inputs taking place during user-product interactions.

In this research the authors focus on comfort triggered by pressure, vibration, and thermal physical inputs as perceived by users. In a first study, a model relating product comfort with the overall user experience satisfaction is developed with data extracted from usability tests. In the second study, two comfort models are obtained from data of usability tests in order to establish a link between discomfort caused by pressure, vibration and thermal physical inputs, while grasping the power tool, with the sensation of pain felt by the user both at hands and in the rest of the body. This way we examine different types of comfort which are felt by the user during product use and relate them to different kinds of pain, which gives us a more detailed insight about the sensory processes taking place and what kind of effects are to be caused should a specific kind of comfort consideration be neglected during product design.

2. Material and methods

2.1 Power tool selection

Six different models of power drills were selected for this research. These products were corded (non battery-operated), with electrical power ratings between 500W and 750W. Table 1 lists the models used.

Tool 1, Tool 2 and Tool 3 were used in the first study, while Tool 4, Tool 5 and Tool 6 were used in the second study.

Table 1: Power tools selected for this research

	TOOL 1 AEG SBE 630R		TOOL 4 Bosch PSB6500RE
	TOOL 2 Practyl Z1J-HF-13C-2		TOOL 5 Ryobi EID 750RS
	TOOL 3 PowerG PT080301		TOOL 6 Titan TTB275DRL

2.2 Study 1: Comfort and user satisfaction assessment

A usability test was organized with Tool 1, Tool 2 and Tool 3. A total of 60 users participated in the test, 20 users for each drill model. The test consisted in drilling holes using tips of various diameters (4, 6 and 8 mm) through a wooden plank with a thickness of 12 mm. The users were asked to drill four holes with each tip. The order of the tips was randomized for each user, and at the beginning of the test it was made sure by the usability test's coordinator that the user was in no condition of fatigue or pain.

After the drilling procedure the user had to fill in a form. The first part of the questionnaire was used to gather sociodemographic information about the subjects. In the second part, the users had to assess acoustic comfort, vibrational comfort, hand pressure comfort and thermal comfort on a five-point Likert scale, as well as overall product comfort on a similar scale.

In order to obtain a logistic binary model, satisfaction had to be dichotomized: satisfaction assessments with values 4 and 5 (high comfort values) were assigned a dichotomized value of 1, while assessment values 1, 2 and 3 were assigned a dichotomized value of 0. Using the SPSS software package, a logistic binary model was then obtained using the dichotomized user satisfaction as a dependent variable, and the comforts triggered by pressure, vibration and temperature as independent variables.

2.2 Study 2: Comfort and pain assessment

A second usability test was done with Tool 4, Tool 5 and Tool 6. A total of 60 users participated in the test. Each drill was used by a different group of 20 users. As in the previous phase, the test consisted in drilling holes using tips of various diameters (4, 6 and 8mm) through a wooden plank with a thikness of 12mm. The users were asked to drill four holes with each tip. The order of the tips was randomized for each user, and at the beginning of the test it was made sure by the usability test's coordinator that the user was in no condition of fatigue or pain.

After the drilling procedure the users had also to fill a form. The first part of the questionnaire was used to gather sociodemographic information about the subjects. The second part included a comfort as well as a pain assessment experienced by the users during the drilling process. The comfort assessment was similar to the one made in Phase 1 of this research: a five-point Likert scale was used to assess acoustic, vibrational, hand pressure and thermal comfort. A first pain assessment was done for the palm of the hands (see Figure 1). The user had to specify in which hand and section he had felt any pain (right hand - left hand, zones A-F) and its intensity in a 8 point scale (no pain, very little pain, little pain, moderate pain, slightly high pain, high pain, very high pain). A second and final pain assessment was done for the rest of the body. The same 8 point pain intensity scale was used. The body locations are shown in Figure 2.

Figure 1: Palm of hand locations for pain assessment

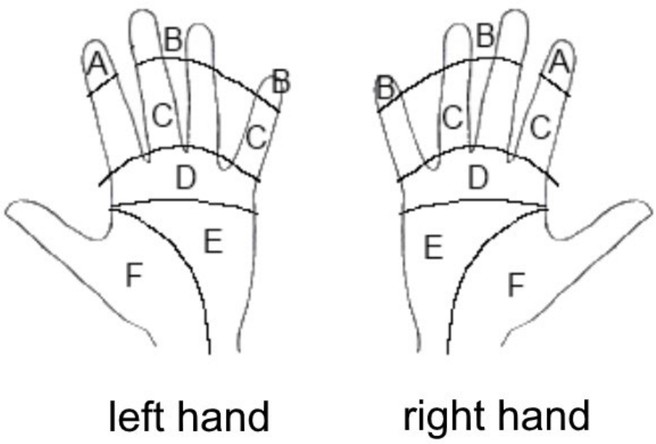
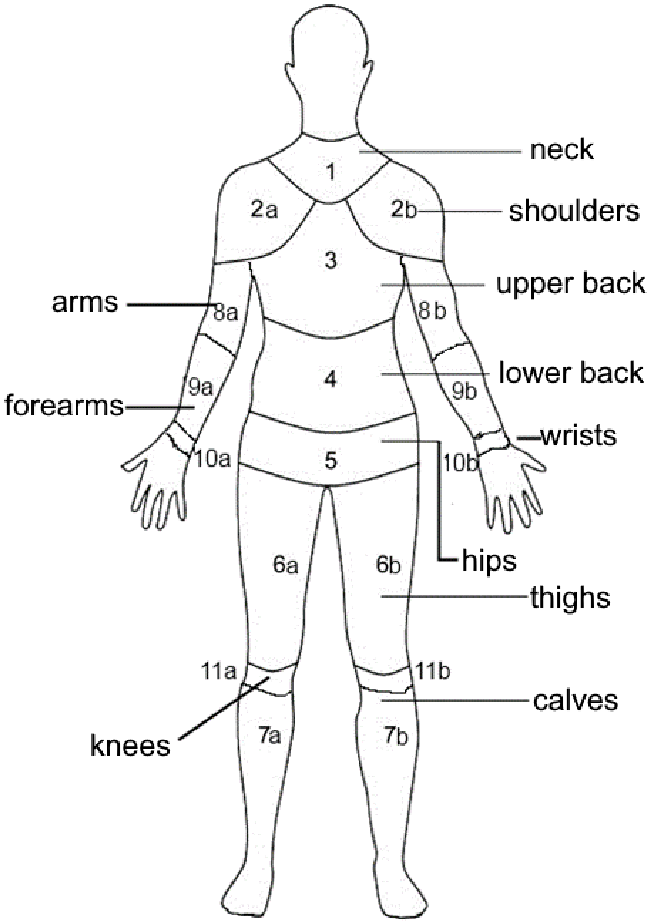


Figure 2: Body locations for pain assessment



Two logistic binary models were obtained in this study with help of the SPSS 16 software package. The first one related pain suffered in the hands to pressure, vibrational and thermalcomfort. The second one related pain in the body to pressure, vibrational and thermal comfort. As in the previous phase, dependent variables were dichotomized.

Comfort model: palm of the hands pain vs. pressure + vibrational + thermal comfort

The dependent variable was the pain felt by the users in their hands, having pressure comfort, vibration comfort and thermal comfort as independent variables. The dependent variable was dichotomized as follows: for each user, the number of locations on the palm of the hands which were assessed with a pain value equal or greater than 2 were counted. A table of number of hand pain locations per user was constructed. The median of hand pain locations was computed. If a user had suffered pain in more hand locations than the median, the dichotomized hand pain value was 1. If the number of locations was below the median, the dichotomized value was 0.

Comfort model: body pain vs. pressure + vibration + thermal comfort

The dependent variable was the pain felt by users in their bodies, having pressure comfort, vibration comfort and thermal comfort as independent variables. This variable was dichotomized using a similar procedure: The number of body parts which were assessed with pain values greater than 2 were counted. A table of number of body pain locations per user was constructed. The median of the body pain locations was computed. If a user had suffered body pain in a number of locations greater than the median, the dichotomized body pain value evaluated to 1. If the number of pain locations was lower, the dichotomized body pain value evaluated to 0.

3. Results

Study 1

The model relating user satisfaction to perceived comfort (pressure, vibration and thermal comfort) is shown on Table 2. All independent variables were significative but thermal comfort.

Table 2: Model relating user product satisfaction with perceived vibrational and hand pressure comfort

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1	**Pressure comfort**	0.917	0.357	6.603	1	0.010	2.501
	Vibrational comfort	0.903	0.446	4.104	1	0.043	2.466
	Constant	-5.613	1.910	8.637	1	0.003	0.004

The resulting binary logistic model in Table 2 corresponds to the following equation, where P_{Sat} is the probability of the user being satisfied with the product experience, and B_{cv} and B_{cp} are the vibrational and hand pressure comfort assessments of the user:

$$P_{Sat} = \frac{1}{1+e^{(5.613-0.903B_{cv}-0.917B_{cp})}}; \quad (1)$$

Study 2

The comfort model relating comfort to pain felt in the hands is shown in Table 3. Only vibrational comfort contributed significantly to the model.

Table 3: Model relating pain on hands with perceived vibrational comfort

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1	**Vibrational comfort**	-0.960	0.292	10.791	1	0.001	0.383
	Constant	3.213	0.876	13.446	1	0.000	24.846

The comfort model relating comfort to pain felt in the body is shown in Table 4. Only pressure comfort contributed significantly to the model.

Table 4: Model relating body pain with perceived hand pressure comfort

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1	**Pressure comfort**	-21.644	3402.079	4.220	1	0.039	0.000
	Constant	25.078	3402.079	5.121	1	0.018	7.786E+10

The following Equations 2 and 3 correspond to the models in Table 3 and Table 4, respectively. P_{hands} and P_{body} are the probabilities of feeling pain in the hands and in the body, while B_{cv} and B_{cp} are the vibrational and hand pressure comfort assessments of the user:

$$P_{hands} = \frac{1}{1+e^{(-3.213+0.96B_{cv})}}; \quad (2)$$

$$P_{body} = \frac{1}{1+e^{(-25.078+21.644B_{cp})}}; \quad (3)$$

4. Discussion

The methodology used, together with the data obtained in the usability tests, allow obtaining three logistic regression models that show a significant influence of specific kinds of comfort to the vital target factors of user satisfaction and pain felt.

User experience satisfaction is influenced by vibrational and pressure comfort (Table 2). This shows that users expect power tools to be comfortable. These two types of comfort affect the nature of the experience using drilling machines. However, thermal comfort does not influence user satisfaction significantly. Product designers should pay special attention to the vibration being felt by the user, as well as the pressure the user needs to exert to make successful use of the machine. Too much vibration or pressure, which implies low comfort levels, will decrease the probability of the user being satisfied with the product (Equation 1).

Pain perception depends on the nature of the discomfort being felt. Vibrational discomfort increases pain perception in the palm of the hands (Table 3). Too much vibration, that is, low vibrational comfort, will increase the probability of feeling pain in the hands (Equation 2). On the other hand, pressure discomfort increases pain perception (Table 4). Too much pressure, that is, low pressure comfort, will increase the probability of feeling pain in the body (Equation 3).

Knowing how different kinds of discomfort affect user experience during product use will allow to improve product design procedures, guaranteeing greater product acceptance and improved ergonomics (Lidwell and Manacsa, 2009; Garía Acosta et al., 2011). The improved comfort knowledge gives product designers important clues about how products will be perceived by users, and will provide important guidance when trying to fine-tune product attributes. Future research should include other types of comfort that may be affecting product use, such as, but not limited to, acoustic comfort. Bigger data samples and different product typologies used under the most varied circumstances, could provide valuable data that would allow for more complete comfort models applicable to users belonging to specific market segments (e. g., professional users, hobbyists, etc.) (Kotler and Armstrong, 2018). Finally, the initial hypothesis should to be tested in further works relating user experience satisfaction to objective values of a set of physical variables perceivable by human sensory channels, so having a global analysis including both subjective and objective users' responses. Such a global analysis could give valuable insights when it comes to improve the product user experience (Schifferstein and Hekkert, 2008).

5. Conclusions

This research has shown that a holistic approach to product comfort may not explain with enough detail the relation between comfort and user experience. The research of different kinds of comfort yields interesting results in relation to user product satisfaction and user pain during product use. Such information may be invaluable in order to successfully position a newly developed product in the market.

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