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RESEARCH ARTICLE

HOW IS YOUR USER FEELING? INFERRING EMOTION THROUGH HUMAN–COMPUTER INTERACTION DEVICES

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Appendix A

Supplemental Page-Level Analysis for Study 2

We conducted an ANOVA to test the hypothesized relationships between negative emotion and mouse cursor movements across the different pages of the website in Study 2. Because no manipulation was made prior to the first page of the website, the mousing behavior should hypothetically be the same between condition groups on this page. However, because we manipulated frustration before users interacted with pages 2, 3, and 4, according to our hypotheses, the mousing behavior should be different on these pages. We present the results in Table A1. As expected, since the manipulation did not precede page 1, both mouse cursor distance and speed were not significantly different between the two conditions. However, as the negative emotion manipulation did precede pages 2, 3, and 4, participants in the negative-emotion treatment group exhibited greater distance and slower speed than did participants in the control group.

Table A1. Study 2 Results

Manipulation		Page 1 None	Page 2 Frustration manipulated before interaction	Page 3 Frustration manipulated before interaction	Page 4 Frustration manipulated before interaction
Group 1: Baseline	Distance (px)	*M* = 15,315.742 *SD* = 9,246.630	*M* = 6,033.361 *SD* = 2,827.731	*M* = 5,212.737 *SD* = 3,563.427	*M* = 8,374.849 *SD* = 4,483.745
	Speed (px/ms)	*M* = .167 *SD* = .076	*M* = .161 *SD* = .072	*M* = .109 *SD* = .059	*M* = .248 *SD* = .132
Group 2: Negative-Emotion	Distance (px)	*M* = 15,918.603 *SD* = 9,038.885	*M* = 10,673.614 *SD* = 9,468.696	*M* = 12,163.959 *SD* = 14,607.910	*M* = 13,472.933 *SD* = 9,294.143
	Speed (px/ms)	*M* = .168 *SD* = .070	*M* = .116 *SD* = .053	*M* = .076 *SD* = .040	*M* = .167 *SD* = .075
Distance F-Test		*F*(1,124) = .137 *p* > .05	*F*(1,124) = 13.703 *p* < .001	*F*(1,124) = 13.271 *p* < .001	*F*(1,124) = 15.220 *p* < .001
Speed F-Test		*F*(1,124) = .940 *p* > .05	*F*(1,124) = 16.393 *p* < .001	F(1,124) = 13.203 *p* < .001	F(1,124) = 17.981 *p* < .001

Appendix B

Supplementary Material for Study 3: Website Screenshots (Examples)

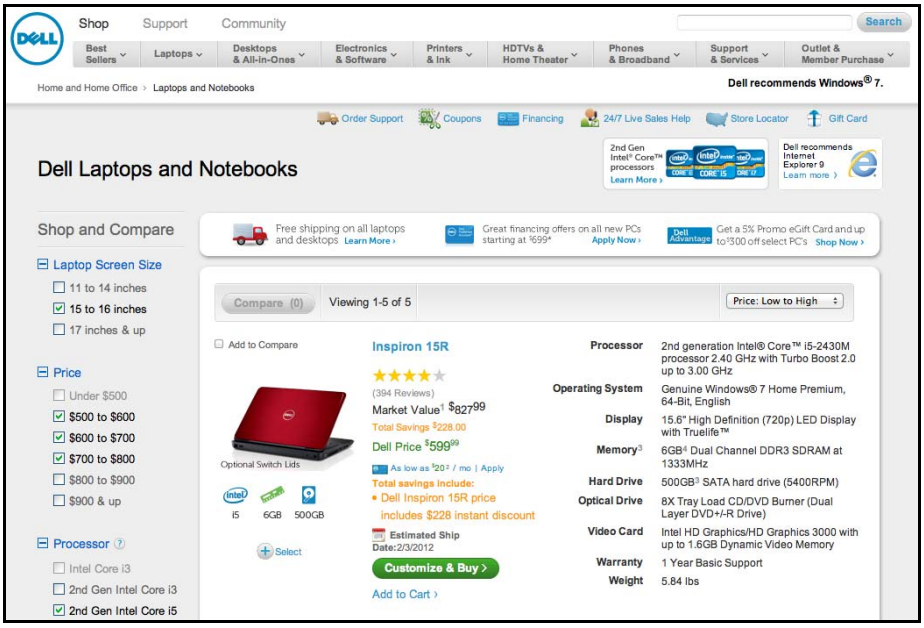

Figure B1. Laptop Configurator (http://www/dell.com)

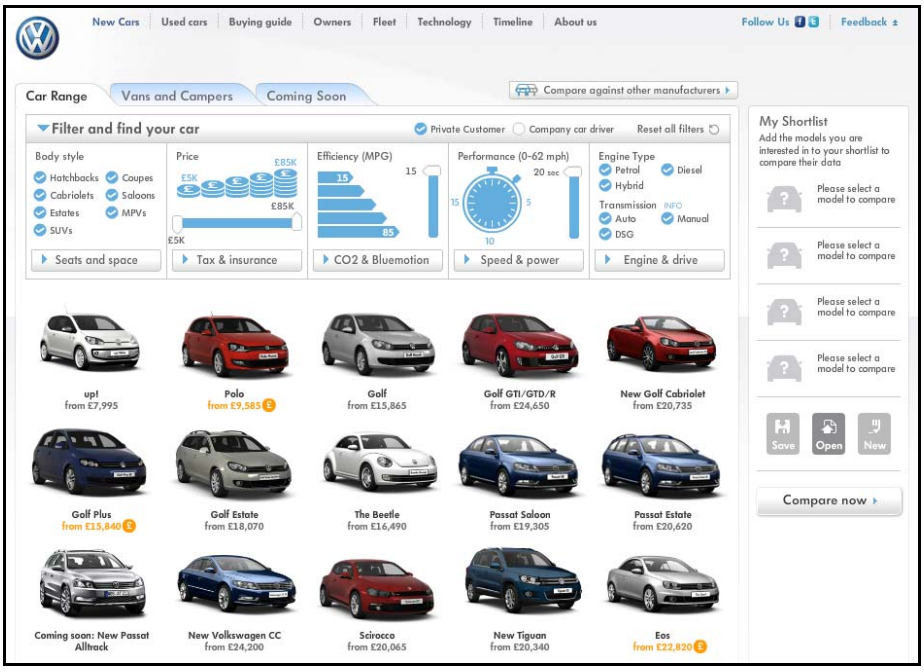

Figure B2. Vehicle Configurator (http://volkswagen.co.uk)

Appendix C

Supplementary Material for Study 3: List of Tasks

Dell (Website: http://www.dell.com)

Task 1 (Maximum allotted time: 3 min): You want to buy a new laptop computer and you already know the specifications which should be included: The display size should be 15–16 inches, it should run Microsoft Windows 7, the weight should be 5–7 lbs., the processor should be an Intel Core i5 and the price should be between US$500 and US$800. Use the configurator to discover which models come into consideration.

Task 2 (3 min): Choose one of the models. You love to chat with your friends, and that's why you want to have a webcam included. Scan the models' specifications to see whether there is a webcam included or not. It should have at least 1 megapixel. You think the i5 processor is too slow so you have decided to choose an Intel Core i7 with at least 1.7 GHz, instead of the i5. Please check whether this processor is available for your model or not. In case it is available, please select it.

Task 3 (2 min): Now you would like to have security software for your new laptop. Choose one and add it to your shopping cart.

Task 4 (2 min): You decide to invest in a 3-year customer care service. Search and add one of the service plans.

Task 5 (2 min): Finish your configuration. Ensure that you haven't made any mistakes during the configuration process and fix any mistakes you may have made.

Volkswagen (Website: http://volkswagen.co.uk)

Task 1 (3 min): You want to buy a new car but you are not really sure about the specifications. Your dream car should have at least 150 PS. It's important for you that your car is efficient and environmentally friendly. That's why the fuel consumption should be at least 60 miles/gallon (MPG) and the CO2 emissions at most 110g/km. The price should be in a range from £20,000 to £30,000. Use the configurator to discover which models come into consideration.

Task 2 (3 min): Choose one of the models. There are different variations of the cars. Please choose a car with at least 150 PS. Moreover, you want to have a car with 5 doors.

Task 3 (2 min): After you have chosen the engine, you would like to have 17 inch tires. The color of your car should be "Reflex Silver Metallic." The interior upholstery (the seats) can be in a color you like best.

Task 4 (2 min): You love your iPod and it's time to choose some additional extras. You would like to hear your music in your car as well. Please search for an iPod interface and add it.

Task 5 (2 min): Finish your configuration. Now it's time to have a look at the financing of the car. Try to figure out your monthly rate if you finance your car for 36 months.

Appendix D

Supplementary Material for Study 3: Additional Statistical Analyses and Robustness Checks

Model Specification

As discussed in the "Model Specification" section of Study 3, our main specification is a fixed-effects regression model of emotions on a set of mouse cursor movement data:

$$\begin{aligned} emotions_{it} = \alpha_i + \beta_1 \cdot cursor\ distance_{it} + \beta_2 \cdot cursor\ speed_{it} \\ + \gamma' \cdot additional\ mouse\ variables_{it} + \lambda_t + \varepsilon_{it} \end{aligned} \tag{1}$$

where i indexes the individuals, t the task number, λ_t represents task-specific effects, and $additional\ mouse\ variables_{it}$ contains left clicks, middle/right clicks, and scrolls.

However, if the unobserved differences across individuals are random,[1] estimates from the random effects model are not only consistent but also more efficient than fixed-effects estimates (Wooldridge 2010). Thus, our second specification is a random effects model:

$$\begin{aligned} emotions_{it} = \alpha_i + \beta_1 \cdot cursor\ distance_{it} + \beta_2 \cdot cursor\ speed_{it} \\ + \gamma' \cdot additional\ mouse\ variables_{it} + \delta' \cdot control\ variables_i + \lambda_t + \varepsilon_{it} \end{aligned} \tag{2}$$

where α_i and ε_{it} are assumed to be independently and identically distributed, and α_i has expectation α and variance σ_α^2. In this specification, we additionally consider the control variables *age*, *gender*, and *country*, as well as *configurator* and *configurator experience*.

For comparison of the results, we also apply a pooled regression model of the following form:

$$\begin{aligned} emotions_{it} = \alpha + \beta_1 \cdot cursor\ distance_{it} + \beta_2 \cdot cursor\ speed_{it} \\ + \gamma' \cdot additional\ mouse\ variables_{it} + \delta' \cdot control\ variables_i + \lambda_t + \varepsilon_{it} \end{aligned} \tag{3}$$

Given our use of two very different product configuration systems, there may be differences in the means of the mouse variables between the two configuration systems. Such differences could be a result of differences in website design (for example, in contrast to Volkswagen's site, Dell's product configurator required vertical scrolling) and are not necessarily related to different emotions. Thus, in order to account for different slopes of the mouse variables across configurators, we analyze additional specifications for the fixed-effects, random-effects, and pooled-regression model, adding interactions terms between the assigned configurator and the different mouse variables.

Results

Table D1 presents a summary of the descriptive statistics of the variables captured in the study, and Table D2 presents the regression results using the pleasure scale of SAM. Models 1–2 of Table D2 are estimates based on fixed-effects specification (see equation 1), while models 3–4 and 5–6 refer to the random-effects specification (see equation 2) and the pooled regressions[2] (see equation 3), respectively. Consistent with our hypotheses, the coefficient of cursor distance was significantly positive across all models ($p < .001$). Moreover, the coefficient of the average cursor speed was significantly negative. This result was very robust to the model specification with at least $p < .05$ across all models. This provides evidence that greater cursor distance and lower cursor speed indicate negative emotion.

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[1] An effect is said to be random if the study contains only a random sample of possible conditions (Field and Field 2013, p. 862). For example, the variable "product configurator" could be considered as random, as we could have used other systems or even more than two configuration systems.

[2] To test the poolability of the subsamples of GER and HK, we conducted a Chow test, that is, we tested whether the coefficients for these subsamples are significantly different (Chow 1960). For the OLS regression, we found in a joint test that the coefficients are indeed significantly different. However, when including the dummy variable *country*, our variables of interest (*distance* and *speed*) do not differ significantly between both subsamples. The corresponding p-values are $p = 0.221$ (Model 5) and $p = 0.436$ (Model 6). Thus, the chosen specification seems to be reasonable for estimating the model.

Summing up the results, we found that the variation of the coefficients of interest was rather low across the models; the coefficients for cursor distance were between .126 and .132, and the respective coefficients for cursor speed varied between -10.30 and -8.08 for the models without interaction effects and between .140 and .155 for the models with interaction effects. This suggests that the results were highly robust to different model specifications.

Table D1. Study Variable Descriptive Statistics

Panel A. Dell Configurator						
	Obs.	**Mean**	**Median**	**Std. Dev.**	**Min.**	**Max.**
Independent Variables						
Distance (px)	200	12,602	11,588	7,989	276	49,205
Speed (px/ms)	200	.137	.12	.06	.04	.39
Left clicks	200	10.94	9	7.33	0	48
Middle/right clicks	200	.08	0	.46	0	5
Scrolls	200	46.21	30	48.85	0	251
Dependent Variable						
SAM Pleasure	200	4.33	4	2.28	1	9
Panel B. Volkswagen Configurator						
	Obs.	**Mean**	**Median**	**Std. Dev.**	**Min.**	**Max.**
Independent Variables						
Distance (px)	200	12,864	11,516	7,515	1,437	40,217
Speed (px/ms)	200	.12	.12	.05	.02	.27
Left clicks	200	17.49	14	13.00	0	79
Middle/right clicks	200	.02	0	.14	0	1
Scrolls	200	5.86	0	13.37	0	108
Dependent Variable						
SAM Pleasure	200	4.31	5	2.19	1	9

Table D2. Regression Results Using the Pleasure Scale of SAM

	Fixed-Effects Model		Random-Effects Model		Pooled-Regression Model	
	(1)	(2)	(3)	(4)	(5)	(6)
Distance (px in '000)	.132*** (.031)	.140*** (.039)	.130*** (.025)	.149*** (.030)	.126*** (.023)	.155*** (.026)
Speed (px/ms)	-10.300** (3.649)	-9.029* (4.312)	-9.185*** (2.658)	-9.468*** (2.811)	-8.076*** (2.301)	-9.949*** (2.528)
Left clicks	-.009 (.011)	-.011 (.022)	-.013 (.011)	-.023 (.018)	-.019 (.012)	-.036† (.019)
Middle/right clicks	.327 (.241)	.257 (.242)	.358 (.235)	.233 (.211)	.410 (.281)	.231 (.210)
Scrolls	.002 (.004)	-.002 (.004)	.003 (.004)	-.001 (.004)	.005 (.004)	-.000 (.004)
Configurator × Distance		-.016 (.054)		-.042 (.046)		-.074 (.045)
Configurator × Speed		-2.567 (6.478)		1.049 (5.506)		5.593 (5.582)
Configurator × Left clicks		.010 (.026)		.020 (.024)		.031 (.025)
Configurator × Middle/right clicks		.654 (1.042)		1.199 (.930)		1.883* (.908)
Configurator × Scrolls		.035*** (.009)		.037*** (.008)		.040*** (.008)
Internet usage			-.011 (.007)	-.011 (.007)	-.011 (.007)	-.011 (.007)
Configurator experience			.195 (.356)	.221 (.356)	.196 (.350)	.240 (.344)
Configurator = Volkswagen			-.063 (.304)	-.354 (.618)	.075 (.305)	-.598 (.686)
Country = Germany			.159 (.374)	.146 (.372)	.155 (.374)	.155 (.367)
Gender = Men			-.226 (.323)	-.188 (.320)	-.243 (.318)	-.210 (.316)
Age			.079† (.045)	.083† (.045)	.081† (.046)	.081† (.044)
Intercept	3.594*** (.330)	3.510*** (.321)	1.881† (1.043)	1.878† (1.128)	1.708 (1.094)	2.021† (1.133)
Task dummies	YES	YES	YES	YES	YES	YES
Individual effects	YES	YES	YES	YES	NO	NO
Observations	400	400	400	400	400	400
R^2	.192[a]	.221[a]	.202	.229	.205	.234
Adj. R^2	.174[a]	.192[a]	.171	.189	.173	.194

Notes: †p < .1, *p < .05, **p < .01, ***p < .001. Standard errors clustered by individuals are in parentheses.
[a]The R^2/adj. R^2 for the fixed-effects regressions are within-R^2, excluding the individual effects. The R^2/adj. R^2 including the individual effects are .532/.400 (Model 1) and .549/.411 (Model 2).

References

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Wooldridge, J. M. 2010. *Econometric Analysis of Cross Section and Panel Data* (2nd ed.), Cambridge, MA: MIT Press.