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Technical Paper:

Automotive Emotions: The Effect of Gender

Marlene Weber & Joseph Giacomin

School Of Design, Brunel University, Uxbridge, Middlesex, UB8 3PH, UK

Corresponding Author: Joseph.Giacomin@brunel.ac.uk

Abstract

The emotional responses to interactions with automobiles can provide insights into what works well and what works less well for people. The measurement of human emotions has thus become increasingly popular in recent times. A question which can however arise is whether statistically significant differences can occur due mainly to gender. The present investigation analysed that possibility with 22 participants who drove a Land Rover Discovery Sport over a route tailored to the stimulation of human emotions. Quantitative and qualitative research methods were combined by performing real-time Facial Expression Analysis via an Affdex Affectiva software tool running on an iMotions platform, and observational analysis by a researcher who noted the likely causes of the stimulated emotions. The research hypothesis was that females would exhibit higher frequencies of emotional expression than males on average. The results from the more than 880 minutes of driving confirmed the research hypothesis. The emotions found to be most frequently expressed by the female participants were anger, surprise and disgust, while for the male participants they were joy, surprise and disgust. The likely stimulating causes which were most frequent with the female participants were dense traffic, navigator alerts and road conditions while those with the male participants were enjoying the car, dense traffic and social interactions.

Keywords: automotive, design, measurement, emotion, driving, gender.

Introduction

The emotional responses to interactions with automobiles can provide insights into what works well and what works less well for people (Gkatzidou et al. 2021). The human emotions influence attention, focus, decision-making, problem-solving, goal generation and performance (Boehner et al. 2007; Eyben et al. 2010). The study of emotions elicited during automobile driving can thus help to better understand driving behaviour, driving performance and driving safety (Giacomin and Ramm 2013). For example, anger has been suggested to facilitate aggressive driving (Wells-Parker et al. 2002) and both frustration and sadness have been suggested to reduce attention (Dula and Geller 2003; Lee 2010; Jeon 2015). And, of course, the emotions stimulated by a product, system or service have traditionally been claimed to play an important role in customer purchasing decisions (Achar et al. 2016; George and Dane 2016).

A question which can arise when interpreting human emotional responses is whether statistically significant differences can occur due to gender. Non-automotive research studies have suggested that females can be more emotionally expressive than males (Wallbott 1988; Dimberg and Lundquist 1990; Briton and Hall 1995 ; Bailenson et al. 2008; Kret and De Gelder 2012). And the expression of positive emotions has been noted more frequently with females (Eisenberg 1995) while the expression of negative emotions has been noted more frequently with males (Evers et al. 1991; Fabes and Martin 1991).

At the present time studies specifically of automobile driving emotions are still limited in number. And the near totality of the existing studies were performed by means of surveys, or in the case of simulator or road driving have involved subjective rating scales or short questionnaires.

Among the more robust findings it was noted that males can be more aggressive when driving (Eagly and Steffen 1986), that males can be more prone to road rage (Wells-Parker et al. 2002), that males can be more likely to express anger via physical aggression towards other drivers (Deffenbacher et al. 2001), that males can be more likely to use the automobile to express their anger (Sullman et al. 2017), that males can show less motivation to comply with traffic rules (Vardaki and Yannis 2013) and that males can be more angered by a police presence while females can be more angered by traffic obstructions (González-Iglesias et al. 2012). Females, instead, have often been reported to often be more anxious when driving (Lin and Chien 2010).

While there have been multiple reports of gender differences in emotional expression while driving, the existing research has focused mostly on a narrow range of driving situations and has been performed mostly by means of surveys, short questionnaires or subjective rating scales. The present study adopted instead both quantitative and qualitative research methods to investigate gender differences over a lengthy and emotionally complex driving route. A total of 22 participants drove a Land Rover Discovery Sport automobile over a 15.2 mile route which took 40 minutes to complete on average. Quantitative and qualitative research methods were combined by performing real-time Facial Expression Analysis via an Affdex Affectiva software tool running on an iMotions platform, and observational analysis by a researcher who noted the likely causes of the emotions. The research hypothesis was that females would exhibit higher frequencies of emotional expression than males on average.

Figure 1: Placement of the video cameras in the automobile.

Experimental Setup

A Land Rover Discovery Sport SE with a 2.0L four-cylinder diesel engine and manual transmission was used. It was provided by JaguarLandRover and was insured for driving by Brunel University. As shown in Figure 1, two video cameras were installed to record the driver's facial expressions and the road environment ahead. The "face camera" was attached to the windscreen in a position which allowed adequate view of the driver's face and which minimised intrusiveness. The "scene camera" was fixed to the headrest of the driver's seat to record the outside view and parts of the dashboard.

All participants drove the same automobile over the same driving route. A researcher was present on the rear seat, checking the proper functioning of the monitoring equipment and taking notes about the emotional expressions and about their likely causes. Video recording was ongoing during the complete drive.

The driving route included a variety of road types and driving situations as suggested by previous studies (Schweitzer and Green 2007; Miller 2013). The distribution of road types was approximately 40% city, 40% country and 20% motorway following previous practice for vehicles of similar market segment (Giacomin and Bracco 1995). The total distance was 15.2 miles and the total time required to complete the drive was 40 minutes on average.

When selecting the driving route attention was paid to incorporating as many as possible of the conditions which have been noted to trigger human emotions. The route therefore involved numerous roundabouts and complex junctions (Funke et al. 2007; Roidl et al. 2013; Lee and Winston 2016), poor surfaces such as potholes or eroded pavement (Roidl et al. 2013; Argandar et al. 2016), locations characterised by reduced views (Roidl et al. 2013), speed bumps (Pau and Angius 2001; Argandar et al. 2016) and bus stops and pedestrian crossings (Deffenbacher et al. 1994).

A full description of the driving route including the exact roads can be found in Weber (2018), Weber et al. (2018) or Weber et al. (2019). A navigator was used to direct the participants and all tests were conducted between 11:00 and 15:00 in the day so as to avoid rush-hour traffic. No studies were conducted under extreme weather conditions.

Facial Expression Analysis

The Affdex Affectiva software tool was run on an iMotions platform (Stöckli et al. 2018) for the Facial Expression Analysis. It provided real-time estimates of the six basic human emotions of joy, sadness, fear, anger, disgust and surprise (Ekman and Friesen 1971; Ko 2018). It provided an evidence score (0 to 100) corresponding to the probability of the given emotion being present at the given point in time. A user selectable threshold value governed the data recording of each emotion. Based on pilot testing, all threshold values were taken to

be between 50 and 70.

Affdex Affectiva also provided a set of action units (AUs) which are contractions or relaxations of one or more facial muscles which in the appropriate pattern provide the evidence of a basic emotion (McDuff et al. 2016). AUs were used to permit data comparisons with the results of previous studies and due to evidence of association between some AUs and the valence of the emotion (Kassam 2010). Further, dependence on only composite measure basic emotions has been discouraged (Tian et al. 2001; Shah et al. 2013) due to findings which suggest that human emotion can sometimes be communicated by as little as a single discrete facial feature (Tian et al. 2001).

In the present investigation the choice of AUs was based mostly on the observation that movements around the eyes and mouth provide the strongest indicators of emotion (Wegrzyn et al. 2017). The six AUs were:

- Lip press: often associated with concentration or anger.
- Lip pucker: often associated with annoyance or anger.
- Inner brow raise: often associated with surprise.
- Brow furrow: often associated with displeasure.
- Lip corner pull: often associated with pleasure.

Participant Selection, Size and Recruitment

A purposive sampling strategy was adopted for the participant selection based on age, gender and driving style. Gender and age were identified via a participant questionnaire and the driving style was classified by means of the Multidimensional Driving Style Inventory (Taubman-Ben-Ari et al. 2004). Since previous research (Turner and McClure 2003) has suggested that driver attitudes and behaviours can be strongly influenced by age, gender and driving style, an approximately even distribution of each was achieved.

Validity criteria for mixed-method research studies (Teddlie and Yu 2007 ; Creswell and Poth 2017) suggested a sample size of 20 to 30 participants, with 8 to 20 participants possibly being sufficient to achieve stable conclusions. A group of 22 participants was selected composed of 10 females and 12 males. The group covered four age ranges (18–25, 26–34, 36–45, 46–55) and five driver types (Angry, Anxious, Dissociative, Distress-reduction, Careful Driver) relatively evenly.

Recruitment was conducted internally at Brunel University via an invitation issued on the university website. Participant selection and all phases of the study were performed under the University's ethics approval.

Data Analysis

For the quantitative data analysis all facial expressions above the predefined threshold were collated for all participants and then divided by gender and either category of basic emotion or category of action unit. For each gender, the average frequencies of occurrence and standard deviations of each category of basic emotion and of each category of action unit were then calculated. To determine whether the basic emotions were dependent on gender a chi-squared test was performed at a p=0.05 significance level. To determine whether the action units were dependent on gender a chi-squared test was also performed at a p=0.05 significance.

For the qualitative data the researcher's identified likely causes were assigned in real time to the corresponding facial expressions via datafile annotation. The likely causes assigned in real time were then later reviewed based on the facial expressions database and the video feed, and where needed revised. If no obvious likely cause could be identified the emotional expression was categorized as no cause assigned (nca).

To ensure data validity an inter-rater reliability test was conducted (Marques and McCall 2005). Two independent researchers who were not associated with the specific investigation were asked to complete the same observational analysis as the researcher for approximately 10% of the database (Armstrong et al. 1997). The degree of agreement between all three researchers was then evaluated by calculating Fleiss' Kappa.

Results

A total of 360 basic emotions and 698 AUs were found in the dataset across the 10 female participants while a total of 238 basic emotions and 739 AUs were found in the dataset across the 12 male participants. The females were found to express on average 36.0 emotions (SD=29.4) during the study while the males expressed on average 23.6 emotions (SD=24.6). Females were found to express 52.7% more basic emotions than males while driving over the same route.

Table 1 provides an overview of the findings regarding the frequency of the human emotions. For the females the most frequent emotions were disgust (30%), anger (29%) and surprise (25%). Instead for the males the most frequent emotions were joy (41%), disgust (21%) and surprise (16%).

Table 2 provides an overview of the findings regarding the identified likely causes. It can be noted that the navigator, dense traffic, enjoyment of the vehicle characteristics and social interactions were all highly influential towards stimulating emotional responses.

Table 3 provides an overview of the findings regarding the frequency of the action units. Females were found on average to express 69.8 AUs (SD=51.1) while males expressed on average 61.6 (SD=46.1) AUs. Females were found to express 13.4% more action units than males while driving over the same route. With respect to the composite measure basic human emotions, the action units suggested greater statistical similarity between the gender groups, age groups and driving style groups.

Basic Emotion	Female Participants		Male Participants	
	Number Recorded	% of total number of basic emotions (360)	Number Recorded	% of total number of basic emotions (283)
Joy	12	3%	116	41%
Anger	104	29%	37	13%
Surprise	90	25%	45	16%
Sadness	32	9%	23	8%
Disgust	108	30%	60	21%
Fear	14	4%	0	0%

Table 1: Frequencies of the basic emotions compared between genders.

Emotion	Female Participants		Male Participants	
	Number Recorded	Cause	Number Recorded	Cause
Joy	8	social interaction	67	enjoying car
	2	road conditions	26	nca
	-	-	22	social interaction
Anger	23	navigator alert	8	dense traffic
	19	navigator check	7	navigator check
	9	sunlight glare	6	navigator alert
Surprise	18	road conditions	10	road conditions
	9	limited viewfield	7	navigator alert
	4	navigator alert	4	sunlight glare
Sadness	15	navigator alert	6	road conditions
	3	navigator check	2	dense traffic
	3	nca	2	navigator alert
Disgust	22	dense traffic	16	dense traffic
	16	road conditions	11	social interaction
	12	navigator alert	9	road conditions
Fear	9	navigator alert	-	-
	3	nca	-	-
	1	dense traffic	-	-

Table 2: Most frequently assigned likely causes of the individual basic emotions.

Action units	Female		Male	
	Number Recorded	% of total number of action units (698)	Number Recorded	% of total number of action units (739)
Brow Furrow	230	33%	111	15%
Lip Pucker	70	10%	44	6%
Lip Corner Pull	35	5%	111	15%
Inner Brow Raise	56	8%	266	36%
Brow Raise	119	17%	111	15%
Lip Press	188	27%	96	13%

Table 3: Frequencies of the action units compared between genders.

Action units	Female		Male	
	Number Recorded	Cause	Number Recorded	Cause
Brow Furrow	50 27 10	navigator check navigator alert dense traffic	34 25 13	navigator check dense traffic road conditions
Lip Pucker	20 10 4	navigator check dense traffic roundabout	8 7 5	navigator check dense traffic roundabout
Lip Corner Pull	14 5 4	navigator check dense traffic limited viewfield	32 22 16	navigator check dense traffic road conditions
Inner Brow Raise	22 8 3	dense traffic infotainment road conditions	34 29 25	road conditions dense traffic navigator check
Brow Raise	25 10 5	road conditions traffic density navigator check	18 13 10	road conditions navigator check dense traffic
Lip Press	35 20 8	dense traffic navigator check slow vehicle ahead	22 18 16	navigator check dense traffic road conditions

Table 4: Most frequently assigned likely causes of the action units.

Brow Furrow (33%), Lip Press (27%) and Brow Raise (17%) were the action units which were most frequent for the females. Inner Brow Raise (36%), Brow Raise (15%), Lip Corner Pull (15%) and Brow Furrow (15%) were most frequent for the male. It can be noted that the AUs which were most frequently expressed by the females and the males differed noticeably.

Table 4 provides an overview of the findings regarding the likely causes of the action units. It can be noted that the navigator, dense traffic, and road conditions were all highly influential towards stimulating AUs.

A chi-squared test of independence was used to test the research hypothesis that females would exhibit higher frequencies of emotional expression than males. It was performed at a 0.05 significance level using five degrees of freedom. The calculations resulted in $\chi 2 = 153.1$ for the basic emotion data and $\chi 2 = 253.1$ for the action unit data. The results suggested p-values which were lower than 0.05 for both the basic emotions and the action units, rejecting the null hypothesis that the basic emotions or action units were independent of gender.

The inter-rater reliability test resulted in a Fleiss' Kappa value of 0.68. Since a value of 0.0 suggests a pure random relationship and 1.0 suggests instead perfect agreement (Xie et al. 2017) the value of 0.68 confirmed that substantial agreement was achieved. The identified likely causes of the individual emotional expressions could therefore be considered reliable.

Discussion

The research hypothesis that females would exhibit higher frequencies of emotional expression than males was confirmed. Both the composite measure basic human emotions and the individual action units exhibited statistically significant differences as a function of gender. The result is in line with the findings of previous studies (Wallbott 1988; Dimberg and Lundquist 1990; Briton and Hall 1995; Kret and De Gelder 2012) and provides support for the suggestions of the benefit of gender-specific features for in-car systems (Saucier et al. 2002; Lin and Chien 2010).

Nuances and deviations with respect to the previous research can however be noted among the elicited basic human emotions. The current dataset suggests fewer expressions of joy by females with respect to males, while previous research studies mostly suggested higher expressions of joy by female participants (Eisenberg 1995). And the current dataset suggested that females expressed anger more frequently than males while previous research suggested the opposite (Evers et al. 1991; Fabes 1991; Sullman et al. 2017).

Nuances and deviations with respect to the previous research can also be noted among the elicited action units. Consistent with previous research (McDuff et al. 2016) the gender differences were found to be smaller in the case of the AUs than with the basic emotions. However, Lip Corner Pull and Brow Raise was encountered more frequently with the females than noted in the previous studies (Schwartz et al. 1980; Dimberg and Lundquist 1990) and Brow Furrow which is often associated with anger was encountered more frequently with the females than the males.

Regarding the identified likely causes of the emotional expressions the present investigation highlighted the importance of a small number of specific conditions. Whether considering the composite basic human emotions or the individual action units involved, the navigator, dense traffic, road conditions, enjoyment of the vehicle characteristics and social interactions were found repeatedly across the dataset. It can also be noted that the navigator and dense traffic were found to repeatedly stimulate negative emotions while social interactions with other people and certain pleasant characteristics of the vehicle interior and dynamics repeatedly stimulated positive emotions.

The study design and data analysis of the present investigation do not permit definitive explanations of the differences with respect to past studies. A few observations can however be made which provide elements which future studies may confirm to have influenced the current results.

First it can be noted that the previous research was performed mostly by means of surveys, short questionnaires or subjective rating scales while the present investigation relied heavily on real-time Facial Expression Analysis. Surveys, short questionnaires and subjective rating scales require data retrieval from long-term memory thus may be influenced to some degree by past experiences. The present investigation was instead based mainly on real-time emotional expressions stimulated by the driving simulator experience, thus involved little or no retrieval from long-term memory. Therefore, some differences in the results may be the result of the differences in format: memory mediated subjective responses versus real-time within context facial observation.

Second it can be noted that the previous research focused mostly on a rather narrow range of driving situations while the present investigation involved instead a lengthy and emotionally complex driving route. Logic would suggest that the route influences the frequency and nature of the emotions which are elicited. Some differences in the frequency of occurrence of the basic emotions or of the action units may therefore possibly be attributable to the differing routes and traffic conditions

A third consideration is the presence of the researcher in the automobile. It has been suggested that the psychological impact of being watched has significant effects on emotion expression (Yu et al. 2015). The presence of cameras and researcher within the automobile may therefore have had some role in the less frequent expression of anger by the male participants with respect to past research studies.

A final consideration is that past research has suggested that females can be more anxious than males when following routes (Lin and Chien 2010). This specific gender difference has been suggested to be a result of the different information processing and wayfinding strategies adopted by females and males, with females using more the landmark strategy and males applying more a Euclidean strategy to orientate (Saucier et al. 2002). The use of a fixed route and of a navigator in the present investigation may therefore have had differential effects on the emotions expressed by females and males.

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