Age- and Gender-Related Studies on Senses of Perception for Human-Vehicle-Interaction

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Abstract: Excess workload in vehicle control and inappropriateness of the common two interaction modalities vision (due to dazzling sunlight or changing lighting conditions) and sound (affected by background noise or superposition of voice from cell phone calls or conversations with passengers) requires to consider ways and means for new interaction capabilities in vehicles. We have investigated haptic force displays for transmitting feedback from vehicular services to the driving person with vibro-tactile elements, integrated into the car seat and backrest. A haptic display would be implicit perceivable, is passive in its attentiveness, and displays private messages (this means, that it is impossible for other persons to receive these informations).

Empirical studies regarding reaction times for the different modalities vision, sound, and touch, as well as age- and gender-dependent evaluations have been conducted, with the aim to identify general conditions for a all-purpose vehicle interaction system and to justify the usage of haptic feedback. Experimental data have been acquired in a simulated driving environment in order to guarantee safety for test persons, repeatability of the experiment itself, and similar conditions for each test run.

Keywords: Multimodal Interaction, Haptic Force Display, User-Centered Design, Performance Studies

1 Related Work, Motivation

It has been proven, that the accuracy of perception is affected by the age, exemplarily for haptic stimuli in [BPN+93]. They found, that threshold mediated by the *Pacinian Mechanoreceptors* increases $2.6dB$ per 10 years (measurements took place on the fingertips). Response time (e.g. hitting the brake pedal of a car when the traffic light turns to red) when processing ordinary stimuli gains with increasing age. Analysis of traffic accidents in finland shows a drastic age-proportional increase, caused by declining speed of information processing and response time [KSB05]. But on the other hand it has been determined, for instance by L. Breytspraak, that experience with a specific task apparently compensates for the decline with age [Bre].

In [SH07], Shaffer and Harrison confirms that (i) human *Pacinian Corpuscles (PC)* decrease in number with advanced age, (ii) vibro-tactile sensitivity involving PC pathways becomes impaired with age, and (iii) older adults ($\overline{x}$=68.6 years) required significantly greater amplitudes of vibration to achieve the same sensation-perceived magnitude, as younger subjects ($\overline{x}$=23.5 years). Likewise, [SMH$^+$04] found that older people experience a decline in the sensitivity of skin, and also have more difficulty in discriminating shapes and textures by touch.

Considering the use of haptics for compensating drawbacks from visual and auditive senses, and accounting the evidenced age-dependency of reaction-times from vibro-tactile stimulation, as well as the matter of fact that population gets increasingly overaged, this necessitates a all-round solution so that touch sensations and proprioception can be observed and interpreted accurately, reliable and fast.

Based on findings from prior experiments [RF08b] we have a detailed look of consequences from the age-dependency for different modalities in this work. Additionally, data is evaluated based on attendees' gender – with the aim to discover possible sex-referred dependency in reaction times.

2 Experimental Setup

Simulation Trace

A movie (length after cutting/editing $11min.22sec.$) from a real driving trip has been captured prior the experiment. Simultaneously, a trace of selected activities (lights on, lights off, turn left, turn right) has been stored in a *.eli*-file (event list).

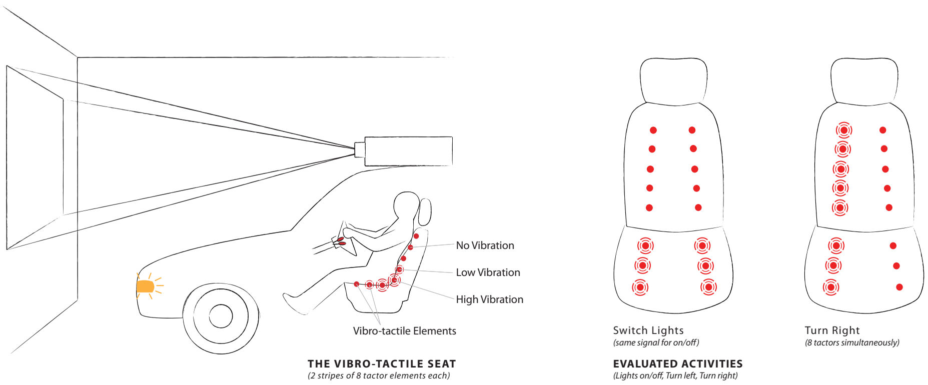

Figure 1: Setup of the performance evaluation system in the garage (left-hand side) and selection of analyzed patterns ("tactograms") (right-hand side).

Hardware Setting

After suitable preparation, the experiment took place in a parked car (type Audi 80). The following list gives an overview about preconditions, experimental setup and processing (see Figure 1 for an illustration of the system setting):

(i) The vehicle is parked in a single carhouse without windows to ensure high contrast for the playback of the pre-recorded test run.

(ii) A high-illuminating video-beamer is placed on the roof of the car, projecting the video on a 2.25x3.15 meter-sized projection screen ahead the front windshield (test participants sitting on the driver seat can see the video in its entire size; projection facilitate a near real-driving behaviour).

(iii) Electrical signals from turn indicator and light switch are picked off and transferred to the computer, hosting playback and evaluation applications. Signal acquisition and processing is done with a Atmel AVR ATmega8 microcontroller, placed on a STK500 development board.

(iv) During experiment execution (play-back of the video), the trace engine processes the pre-recorded trace file, synchronized to the video, and randomely selects a modality (by now, either a visual, auditory, or haptic signal) for user-notification. Concurrently, a timer is started, measuring the delay between notification and corresponding user's reaction. To avoid annoyance from unintentional environmental noise (and to enhance the quality of the perceived auditory signal), experiment attendees are equipped with a stereo headphone (type AKG K55).

(v) The experiment procedure itself, which takes about 15 minutes in time, is fully automated (a supervisor only ensures correct experiment processing). For each notified action a dataset is stored, containing notification time, the channel of sense (modality) used for the notification, user's reaction time, and the switch firstly activated by the user (to determine, if the user has activated the right or an incorrect switch).

Test participants

We hired 18 persons to participate on the experiment. All of them (83.33% male, 16.67% female) were university students, research staff and friends with a valid driving-licence, in the age-range from 18 to 38 years (male, $\overline{x} = 24.80$, $\sigma = 5.41$) respectively 22 to 30 years (female, $\overline{x} = 26.00$, $\sigma = 4.00$). Beside weight and size, driving experience in years has been inquired during the experiment. This value is between 1 and 20 years for male participants ($\overline{x} = 6.93$, $\sigma = 5.19$) and between 4 and 12 years for female attendees ($\overline{x} = 8.00$, $\sigma = 4.00$). As each attending person got it's driving license at the (earliest) age of 18 years, person's age correlates fully with driving experience.

3 Results

3.1 Modality-based

Attribute	Min x_{min}	Max x_{max}	Mean $\overline{x}$	Median $\widetilde{x}$	Std.Dev. σ
Confidence Interval 5% (752 Datasets, 94.94%)					
ALL	281.00	1985.00	889.22	812.00	349.95
Visual	391.00	1922.00	784.25	703.00	295.81
Auditive	641.00	1984.00	1129.61	1078.00	269.58
Haptic	281.00	1625.00	690.62	641.00	255.85

Table 1: General statistics on reaction times for a 5% confidence interval and all test persons, separated by modality (lower values indicate better performance). Reactions from haptic stimuli performs best, far ahead of visual and auditive stimulations.

As we already investigated in a previous experiment (for detailed findings see [RF08b]), drivers reaction on haptic stimuli provides best results (see Table 1 and Figure 2). Mean reaction time from haptic notifications ($\overline{x_h} = 690.62ms$) is 13.56% faster than mean reaction from visual ($\overline{x_v} = 784.25ms$), and 63.56% faster than from auditive ($\overline{x_a} = 1,129.61ms$) stimulation. Furthermore we have inspected the linear trend lines for individual reaction times, and have observed that this line faces downwards for all three notification modalities. As the experiment started immediately – without a practice run – this is clearly an indicator that training increases personal reaction performance (these assumptions have already been studied in a self-contained experiment on *haptic space awareness* [RF08a]).

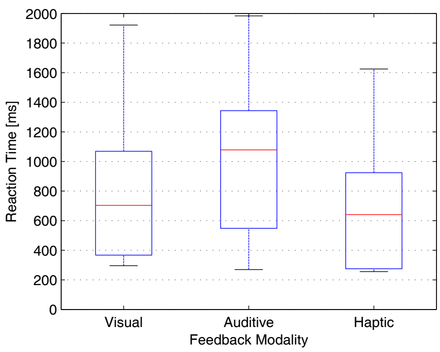

Figure 2: Boxplots for the different modalities shows that reations from haptic stimuli performs best (lower values indicate faster reactions for $x_{h,min}$, $x_{h,max}$, $\overline{x_h}$).

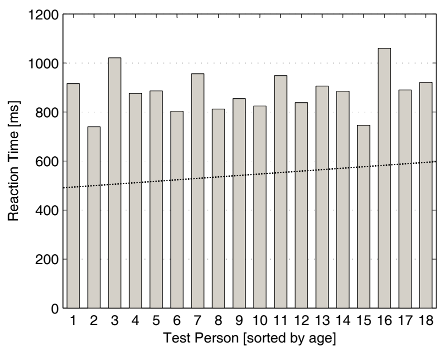

Figure 3: Histogram of mean reaction times and overlaid linear trend line, ascending sorted by drivers age, shows that reaction time declines with increasing age.

3.2 Gender-related

Attribute	Min x_{min}	Max x_{max}	Mean $\overline{x}$	Median $\widetilde{x}$	Std.Dev. σ
Male Participants, Confidence Interval 5% (628 Datasets, 79.29%)					
ALL	281.00	1985.00	872.96	782.00	348.80
Visual	391.00	1922.00	766.06	672.00	286.35
Auditive	641.00	1938.00	1111.01	1047.00	267.36
Haptic	281.00	1625.00	670.30	625.00	252.50
Female Participants, Confidence Interval 5% (124 Datasets, 15.65%)					
ALL	500.00	1984.00	971.59	882.50	345.50
Visual	547.00	1828.00	873.85	734.00	327.85
Auditive	828.00	1984.00	1225.77	1172.00	264.11
Haptic	500.00	1594.00	788.65	711.00	252.24

Table 2: Statistics on reaction times for test persons, separated by modality and gender. Male test persons responds faster to stimuli than female; this is valid for all 3 modalities.

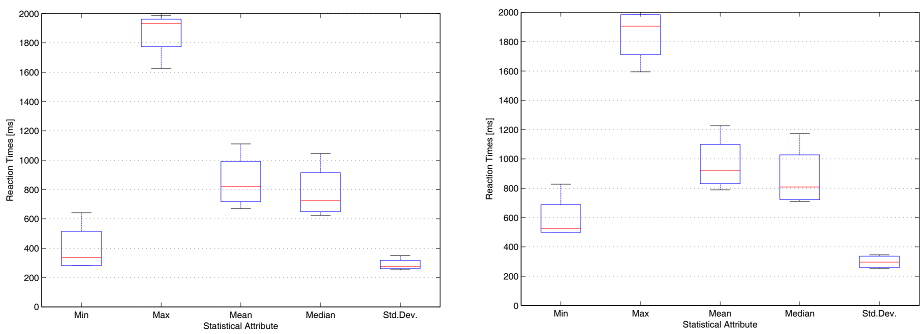

Figure 4: Boxplots shows differences between male (left) and female (right) participants. We can indicate a salient contrast in minimum response time in favor of male.

The gender-related analysis of test data provide, opposed to our hypothesis, following results (these findings have to be handled with care because the two classes are not uniformly distributed): (i) Average reaction of male test persons is better than reaction of female persons – the improvement is (based on the mean values of all modalities) +11.13%. A similar result applies again to the three modalities individually: Improvement, based on mean values, is +10.33% for auditive, +14.07% for visual, and +17.66% for haptic notifications; (ii) Sequence of reaction times (haptic ahead of vision and auditive) is not gender-dependent (and therefore equal for male and female classes). Both groups reacted fastest on haptic stimulation ($\overline{x_{male,h}} = 670.30ms$, $\overline{x_{female,h}} = 788.65ms$), and slowest on notifications via sound-channel ($\overline{x_{male,a}} = 1,111.01ms$, $\overline{x_{female,a}} = 1,225.77ms$).

3.3 Age- and Driver experience-related

As discussed in the related work section above, it should be possible to discover a compensation of age-influenced degradation by task experience. We have investigated this question by analyzing data according to driving experience (or the age of the person, as this value offers exactly the same information).

Grouping by Median: First investigation on age-dependency has been done by grouping data into one class of younger (below 25 years) and another of older (25 years or above) people. The border of 25 years has been choosen according to the median value over all test persons. Evaluations show that the mean reaction

Attribute	Min x_{min}	Max x_{max}	Mean $\overline{x}$	Median $\widetilde{x}$	Std.Dev. σ
Younger Participants, Confidence Interval 5% (332 Datasets, 41.91%)					
ALL	281.00	1985.00	870.94	781.00	364.94
Visual	391.00	1875.00	755.35	672.00	272.79
Auditive	688.00	1938.00	1169.39	1101.50	286.53
Haptic	281.00	1594.00	660.09	610.00	259.77
Older Participants, Confidence Interval 5% (419 Datasets, 53.03%)					
ALL	328.00	1984.00	903.68	828.00	337.37
Visual	406.00	1922.00	809.37	711.00	313.34
Auditive	641.00	1984.00	1101.19	1070.00	254.14
Haptic	328.00	1625.00	715.23	656.00	250.95

Table 3: Statistics on reaction times for test persons, separated by modality and age. We can indicate a degradation in reaction time when comparing younger to older attendees.

time (combined for all stimuli) of the older group ($\overline{x_o} = 903.68ms$) takes 3.76% longer than that of the younger group ($\overline{x_y} = 870.94ms$). Better results can be realized when considering notification channels individually: Degradation reaches 8.35% from haptic stimuli, and 7.15% from visual stimulations. The sound-channel performs contrarily – the older group of test participants achieves better results in the amount of 6.19% compared to the younger group of attendees.

As these results are not very expressive, probably caused by the fact that our test candidates are all in a relatively close age range of 28 ± 10 years (especially when comparing to the analysis presented in [SH07]), we did a second experiment, considering persons individual age instead of the grouping into regions.

Sorted by Age: In a second series of tests, we re-sorted our database ascending according to the age of the test persons. The histogram of mean reaction times (see Figure 3) shows, that overall reaction time increases with advanced age; the overlaid linear trend line confirms this performance-degradation for older test attendees (depicted by a strong ascent of the trend line). This trend can also be observed when considering the three modalities individually (not illustrated).

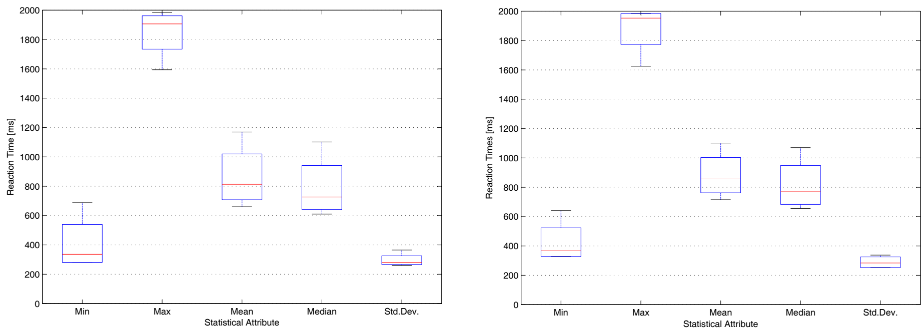

Figure 5: Boxplots for younger (left) and older (right) test participants shows only little difference between the 2 classes.

4 Conclusions and Further Work

We have investigated the performance of different interaction modalities in the automotive domain. Especially we were interested in the results for the sense of touch and have observed that it – as alternative or add-on to the modalities vision and sound – has a number of potentials:

(i) **Reaction time:** Vehicle control tasks, such as initiating turns or switching lights, are faster performed when notificated via haptic stimuli, followed by stimulation from visual and auditive modalities. As haptic force is transferred implicitly and passive to the driver, this modality has the potential to reduce cognitive load and to increase driving comfort.

(ii) **Gender-dependency:** The gender-related comparison of test attendees shows interesting results (although the group of female persons is with an amount of 16.67% not too representative). Male test persons respond faster to stimulations (for each of the three modalities) than female one. We have identified highest percentual increase for reactions on haptic stimuli (+17.66%); the order of modalities based on reaction performance (haptic ahead of visual and auditive) is equal for both groups of test participants.

(iii) **Age-dependency and Driving Experience:** It has been proven that reaction times from (vibro-tactile) stimulations depends on person's age. We determined only little difference of 3.76% when dividing data sets into 2 groups (younger and older people), separated by the age's median (25 years); we got better results when looking on the three modalities isolated – a degradation of 8.35% from haptic stimuli, and 7.15% from visual stimulations, but an improvement of 6.19% for reaction times on auditive notifications. A potential reason for this slight disparity could be constituted by the fact, that the range between minimum and maximum age is rather small. Better results should be achieved when using one group of relatively young persons (closely around 20 years) and one with pretty old people (around 60 years).

When considering the mean values of individual reaction times, ordered by the age of the driver, it is clearly recognizable (e.g. by inspecting the linear trend line) that reaction time declines for older test attendees (this tendency is confirmed when evaluating the three modalities individually).

Currently, we are defining a "Real Driving Experiment" to validate data from the here presented trace-driven simulation in a authentic road traffic environment.

References

[BPN+93] A. J. Brammer, J. E. Piercy, S. Nohara, H. Nakamura und P. L. Auger. Age-related changes in mechanoreceptor-specific vibrotactile thresholds for normal hands. *The Journal of the Acoustical Society of America*, 93(4):p.2361, April 1993.

[Bre] Linda Breytspraak. Center on Aging Studies, University of Missouri-Kansas City. Website, last retrieved July 09 2008. `http://missourifamilies.org/quick/agingqa/agingqa18.htm`.

[KSB05] Konrad W. Kallus, Jeroen A. J. Schmitt und David Benton. Attention, psychomotor functions and age. *European Journal of Nutrition*, 44(8):465–484, December 2005. ISSN: 1436-6207 (Print) 1436-6215 (Online).

[Mil68] R. B. Miller. Response time in man-computer conversational transactions. In *Proceedings of AFIPS Fall Joint Computer Conference*, Jgg. 33, 1968. Pages 267–277.

[RF08a] Andreas Riener und Alois Ferscha. Raising awareness about space via vibrotactile notifications. In *3rd IEEE European Conference on Smart Sensing and Context (EuroSSC), Zurich, Switzerland*, Lecture Notes in Computer Science (LNCS). Springer Berlin / Heidelberg, 2008. Notification pending.

[RF08b] Andreas Riener und Alois Ferscha. Simulation Driven Experiment Control in Driver Assistance Assessment. In *12th IEEE International Symposium on Distributed Simulation and Real Time Applications, Vancouver, British Columbia, Canada*. IEEE Computer Society, October 27–29 2008. In press.

[SH07] Scott W Shaffer und Anne L Harrison. Aging of the Somatosensory System: A Translational Perspective. *Physical Therapy*, 87(2):193–207, February 2007.

[SMH+04] J. A. Smither, M. Mouloua, P. A. Hancock, J. Duley, R. Adams und K. Latorella. *Human performance, situation awareness and automation: Current research and trends, Chapter Aging and Driving Part I: Implications of Perceptual and Physical Changes*. Erlbaum, Mahwah, NJ, 2004. Pages 315–319.

[SP05] Ben Shneiderman und Catherine Plaisant. *Designing the User Interface: Strategies for Effective Human-Computer Interaction.* Pearson Education, Inc., Addison-Wesley Computing, 2005. 4th edition, ISBN: 0-321-19786-0.

[TD74] Charles J. Testa und Douglas B. Dearie. Human factors design criteria in man-computer interaction. In *ACM 74: Proceedings of the 1974 annual conference*, New York, NY, USA, 1974. ACM. Pages 61–65.