Interacting in Desktop and Mobile Context: Emotion, Trust, and Task Performance

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Abstract. The Personal Assistant for onLine Services (PALS) project aims at attuning the interaction with mobile services to the momentary usage context. Among other thing, PALS should adequately address emotional states of the user and support users building up an adequate trust level during service interactions. In an experiment, participants performed interaction tasks with mobile services, on a small handheld device or a laptop. Before each task session, they watched film clips with different emotional impact (i.e. valence and arousal). In addition to performance measures, we measured trust and heart rate. In the handheld condition, task *performance* was substantially worse and showed a more extensive navigation path (i.e. more 'wrong' hyperlinks) to find the target information. Furthermore, during the experiment *trust* in the web services hardly increased in the handheld condition whereas trust substantially improved in the laptop condition. Device and service proved to be the major factors that determine the user experience. There is a clear need to improve the mobile interaction with web services in order to establish an adequate performance *and* trust level (e.g. by attentive interactive displays).

1 Introduction

Due to the development of (wireless) networks and mobile devices, an increasing number and variety of users can access electronic services in a continuous changing usage context. The PALS project aims at a "Personal Assistant for onLine Services", which attunes the user interface to the momentary, individual user interests, capacities, usage history, device and environment. PALS will be developed using a cognitive engineering development approach that provides theoretically and empirically founded concepts for adaptation [8]. A scenario analysis and literature research provided high-level user requirements [12]. Human-Computer Interaction (HCI) knowledge and enabling technologies are lacking to fully realise the identified user requirements, in particular with respect to (1) how to address user's momentary attention, emotion and trust, and (2) how to dynamically structure navigation and derive a user model.

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Nagata [11] provides the first results of the study on *attention*, showing that disruptions in a multitasking setting have a critical impact on a person's attention, limiting task performance, in particular for mobile devices compared to desktop. The disruption is larger when it appears on the device (e.g. instant messaging) than when it comes from an "external object" (e.g. a phone call). In particular for the mobile device, the expectation by the user of receiving an interruption decreased the disruption effect. These results provided an empirical foundation for design concepts to support users' attention by mediating interruptions and an attentive interactive display for better web task performance.

Herder and Van Dijk [3] show the first developments on the technology for adapting the *navigation* structure and deriving *user models*. This adaptation is based on the notion that user navigation paths indicate user interests and navigation strategies. From navigation paths one can predict "lostness in hyperspace" and "navigation efficiency and effectiveness". Navigation structures are modelled as graphs and user navigation is viewed as an overlay of the site graph.

This paper presents a study on *emotion* and *trust* as important elements of the user experience with mobile services. PALS should adequately address emotional states of the user and support users building up an adequate trust level during service interactions. In a similar way as for attention, we first need insight in the effects of device and emotional state on user behaviour and subjective trust in order to create and improve design concepts.

2 User Experience

2.1 Emotion

Human behaviour comprises physical, cognitive and affective processes. From the 90's, researchers started to study affection in more detail providing new insights in user experience (e.g., Picard, 1997). For example, Klein, Moon, and Picard [7] showed that "emotional support", consisting of sympathy and compassion expression, leads to less frustration and more prolonged interaction with a computer game. Norman [13] stated that a positive emotional state leads to divergent and creative thinking and problem solving. On the other hand, a negative emotional state causes tunnel vision and higher concentration on the task at hand. PALS should take into account the user's emotional state and possible effects of the human-computer interaction on these states. Based on the Pleasure-Arousal-Dominance (PAD) model of Mehrabian [1], we distinguish two dimensions to define the emotional state: the arousal level—low versus high—and the valence—positive versus negative. We do not distinguish a separate dominance dimension like the original PAD-model, because the dominance scale proved to explain the least variance and had the highest variability in terms of its inferred meaning in previous research [14].

The first emotion experiment will investigate the effects of device type (iPAQ versus laptop) and emotional state on user's behaviour and trust.

2.2 Trust

In addition to the importance of emotion, trust has being received more attention due to the development of e-commerce services and privacy issues. Trust is being viewed as an important constraint for establishing successful financial transactions and sharing of information in (mobile) network environments [6],[9],[2]. Therefore, PALS should support the realisation of an adequate trust level. User interface appearances, personalisation elements and interaction aspects prove to affect trust [5] and we assume that emotion plays a role in these effects. Trust depends on persistent, competent behaviour of a system that has a purpose of serving the user. It develops as a function of experience, and is influenced by errors from the system, interface characteristics and individual differences on part of the user [10].

Table 1. The target emotional states and description of the film clips

		Valence	
		NEGATIVE	**POSITIVE**
Arousal	**HIGH**	 "**Koyaanisqatsi**" Several high-speed video fragments depict commuters in a station, highway scenes and crowds of people. The music is choir music with a repetitive nature. The duration of the clip is 2 min. 31 sec.	 "**Blues Brothers**" The two main characters attend a church service where the reverend and the choir perform "The Old Landmark". The duration of the clip is 2 min. 55 sec.
	LOW	 "**Stalker**" Two persons, filmed from behind, sitting on a moving train. The clip is black and white and no music was played here, only the sound of the train is heard. The duration of the clip is 2 min. 6 sec.	 "**Easy Rider**" The three main characters ride their motorcycles on a desert highway. The soundtrack is the song "The Weight" played by "The Band". The duration of this clip is 2 min. 38 sec.

3 Experiment

This first experiment should provide insight in the relations between emotion, device, trust and performance, in order to develop a personalisation mechanism that estab-

lishes adequate user behaviour and an appropriate sense of trust for different interaction devices and emotional states. To induce specific emotional states (high and low arousal, positive and negative valence), the participants view film clips and listen to sound tracks with different emotional impacts (see Table 1). Subsequently, they perform tasks with four web services on two different devices, and fill in trust questionnaires. The tasks consist of searching for information and executing financial transactions.

We expect that the mobile device will lead to less efficient performance on these services, compared to a desktop computer. In particular, the experiment tests if emotional state affects performance and trust, and if the effect (size) is related to usage of a specific type of device. In this way, the experiment investigates how trust builds up for a mobile and a desktop device, and whether there are differences that should be addressed by PALS. In this experiment, we investigate the effects for users that already have experience with computers and Internet.

3.1 Method

3.1.1 Experimental Design

A 2 (device) x 2 (valence) x 2 (arousal) mixed model design was adopted, with device as a between subjects variable, and valence and arousal as within subjects variables. Each subject viewed all the film clips and worked with all the services.

3.1.2 Participants

Twenty-four (12 male, 12 female) students participated in this experiment. Mean age was 21 years (min. 18 and max. 26 years). The participants used a PC or laptop and the Internet on a daily basis and used various web services at least once a week. Most of them had never before used a handheld computer.

3.1.3 Stimuli

Five film clips were used in this experiment. Four of them were used previously in a study by Wensveen, Overbeeke, and Djajadiningrat [16] and were validated to induce the target emotional states. Table 1 summarizes the film clips that were used. The presentation order of these film clips was balanced across participants to rule out possible order effects.

The fifth clip was an emotionally neutral film, which showed a busy shopping street with corresponding sound. During the tasks, the soundtrack of the clip played on at a lower volume.

3.1.4 Tasks

The web tasks consisted of searching for information and executing financial transactions with four web services. Two of these four web services were current “com-

mercial" sites, the site of the Rabobank, which is a Dutch bank, and the site of Gouden Gids, which is the Dutch Yellow Pages. Two other sites originated from the Microsoft .Net software development environment: a book store site and a stockbroker service. Each task for a specific service had five alternatives, designed in such a way that they could be compared on execution time and number of steps, but with different parameters. The presentation order for the web services and alternatives was balanced, to minimise possible order effects. The description of the web sites and tasks can be found in Table 2

Table 2. The description of the web services used in the experiment

Web site	Task
www.goudengids.nl	**Looking up information on restaurants, swimming pools, and cinemas.** - Type the name or branch in the search field and hit "Find". - Choose the appropriate item from the search results. - Click it for more detailed information. - Find the specific information item (e.g. telephone number).
Www.rabobank.nl	**Looking up information on insurance, bankcards, and accounts.** - Click on the appropriate link in the main menu on the homepage. - Click on the appropriate link in the submenus on the next 2 pages. - Read and scroll to the specific information item.
Book site	**Compare book prices.** - Type in the name of the first book or author in the search field. - Remember the price. - Type in the name of the second book or author in the search field. - Compare the prices.
Stocks site	**Buying stocks.** - Log on to the web site with user name and password. - Navigate to the search field and type in the name of the company. - Remember the code and navigate to the "Buy" field. - Enter the code and number of stocks, and click "Buy". - Navigate to the portfolio, and remember the amount of money.

3.1.5 Device

The participants used one of two different devices for interacting with the web service. The first was a Compaq iPAQ 3800 Handheld Computer. This device uses touch screen and pen-based navigation and input. The screen resolution was 320 x 240 pixels. The second device was a Sony VAIO Notebook with standard keyboard and mouse for user input. The screen resolution of the notebook was 1024 x 768 pixels. Both devices used Wireless LAN to connect to the Internet. During the whole experiment, the connection was excellent. Browsing was done using Microsoft Internet Explorer. All the instructions and questionnaires were shown on another notebook, which was placed on the table in front of the participant. The answers to the questionnaires had to be typed in on this notebook.

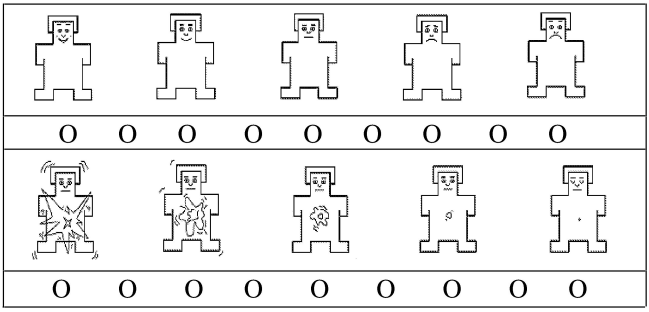

Fig. 1. The valence (top) and arousal (bottom) scales of the Self Assessment Manikin [1]

3.1.6 Measures and Questionnaires

As each subject had to complete five sessions with four services each, and the questionnaires had to be filled out after every service, the questionnaires had to be brief.

Measurement of emotion is done using the Self-Assessment Manikin (SAM). This subjective scale, developed by Lang [1] is based on the PAD model of emotion and measures emotion on the three dimensions of valence, arousal and dominance. The scale consists of three rows of cartoons, on which the participant has to characterize the experienced emotion. When used in studies, the dominance scale proved to explain the least variance, and had the highest variability in terms of its inferred meaning. Therefore, for the present experiment, the dominance scale was omitted. Figure 1 shows the SAM scale.

The trust questionnaire was based on a scale developed by Jian et al. [4]. As the original was too cumbersome to fill out after each task (i.e. interaction with a web service), an adapted version was developed. It consists of three questions that measure the elements of the definition of trust proposed here. Question 1 concerns the service-oriented attitude and question 2 the quality of persistent and competent behaviour. The third question asks directly to what extent the user trusts the service. Trust was measured on a 7-point scale; a higher score corresponded with a higher level of trust. To see whether participants discriminated between trusting the web service and trusting the device, trust in device was measured with a similar questionnaire as described above. This measure was only taken prior to and after the experiment. Reliability of the questionnaire is assessed in the results section.

For every service, effectiveness and efficiency were measured. Effectiveness was defined by correct completion of the task. Efficiency was defined by time on task in seconds, number of typing errors (that were corrected) during the task, and number of extra links that were clicked. By comparing the navigation path of the user with the optimal path, in terms of number of links, this last measure is obtained. The optimal path of navigation for every service was established prior to the experiment. In addition, subjective mental load was measured using the one-dimensional Rating Scale Mental Effort [17]. In this experiment, a digital version of the RSME was used. Par-

ticipants could move a pointer over the scale using the mouse, and click the appropriate score, ranging from 0 to 150.

Recording heart rate (HR) was done using a Vitaport recorder system and software. Three electrodes were attached to the participants' chest for the duration of the experiment. Afterwards, the duration between two beats in the raw data was sampled with a frequency of 4 Hz. The mean HR for any given period is obtained by averaging over these samples. HR is measured as number of beats per minute (bpm). In addition, heart Rate Variability (HRV) was measured as an indication of the level of arousal.

3.1.7 Procedure

In short, the procedure consisted of:

- Briefing and instruction
- Trust questionnaire
- Training on the device
- Neutral session
  - Film clip
  - SAM questionnaire
  - Four tasks
  - After each task: RSME & trust questionnaire
- Four experimental sessions
  - Film clip
  - SAM questionnaire
  - Four tasks
  - After each task: RSME & trust questionnaire
- Trust questionnaire & debriefing

Participants were told that they participated in a usability experiment and were asked to perform the tasks as quickly and as accurately as possible. They rated their trust in the device that they would be using, either the laptop or the iPAQ. Then the baseline HR measure was taken. The subject was connected to the Vitaport and asked to remain calmly seated for a period of 5 to 7 minutes. After this, a short training session on the device took place. With the experimenter present, subjects completed two tasks to familiarize themselves with the device and questionnaires. After receiving feedback on performance, there was an opportunity to ask questions.

Subjects were left alone in the darkened room, with enough illumination to distinguish the keys on the keyboard of the notebook. In the first session, the neutral film clip was shown. After the film, subjects filled out the SAM questionnaire, and proceeded with the four web services. The soundtrack of the film played on at a lower volume. After each service, the RSME and trust questionnaire were filled out. Upon completion of the four services, the sound of the film was turned off and the SAM questionnaire was presented again.

Similar to the first session, four additional sessions were completed, in which the subjects viewed all the film clips. Between each session, a moment of rest was provided. Once all the sessions were completed, subjects again rated their trust in the device and were debriefed on the true nature of the experiment.

3.2 Results

3.2.1 Measurement Assessment

As the *HRV* measure did not discriminate between conditions, this measure is omitted from further analysis.

A reliability analysis for the *trust* questionnaire showed that questions 1 and 2 correlated for .823 and both 1 and 2 correlated .576 with question 3. Cronbach's alpha for the questionnaire was .85.

3.2.2 Emotion Manipulation

A repeated measures ANOVA was performed on the averaged arousal and valence scores for the SAM questionnaire as well as HR during film viewing, and compared to the neutral first session. Both arousal and valence showed significant main effects ($F(4, 92) = 19.10$; $p = 0.000$ and $F(4, 92) = 17.84$; $p = 0.000$, respectively). Post-hoc analysis revealed that only the high arousal, positive valence and low arousal, negative valence conditions did significantly differ from baseline ($p = 0.000$ for both conditions). Figure 2 shows the target emotional states, as described in Table 1, and the actual SAM scores after the film clip.

A main effect of HR was found between conditions ($F(4, 88) = 6.63$; $p = 0.000$), i.e. all conditions showed a lower HR than baseline (average 73.9 for conditions and 77.8 for baseline). Post-hoc analysis revealed no significant differences between either high or low arousal ($p = 0.366$) and positive and negative valence ($p = 0.974$). Thus, the emotional induction procedure was successful for two distinct emotional states, although no physiological evidence (e.g. differences in HR) for this induction can be found in the results.

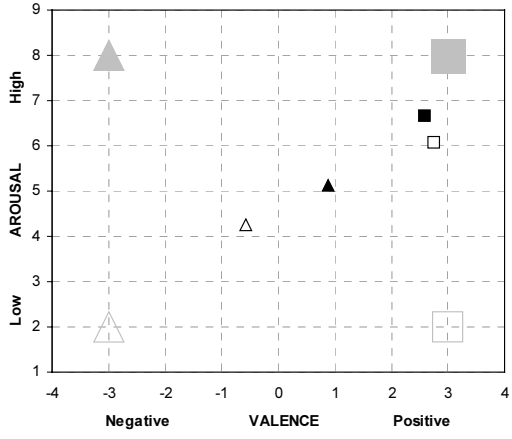

Fig. 2. The target emotional states (big, gray) and the actual SAM scores after the film clip (cf. Table 1)

3.2.3 Effects of Device on Performance and Trust

A significant main effect of device is found for time on task ($F(1, 17) = 58.27$; $p = 0.000$), number of typing errors ($F(1, 17) = 22.94$; $p = 0.000$) and number of links ($F(1,17) = 12.42$; $p = 0.001$). No main effect of device was found for mental effort. Averaged over services, subjects took longer to perform the services with the iPAQ (127 sec.) than with the laptop (55 sec.). In addition more errors and wrong links occurred with the iPAQ (1.0 and 1.0 respectively) than with the laptop (0.5 and 0.4 respectively).

Wilcoxon Matched Pairs test revealed an overall increase of trust in the laptop as a result of experience with this device. The scores after the experiment on the servitude ($Z(12) = 2.67$; $p < 0.01$), persistence ($Z(12) = 2.37$; $p < 0.05$) and trust ($Z(12) = 2.67$; $p < 0.01$) questions all differed significantly from the pre-measurement. Figure 3 shows these results. Scores for the iPAQ did not differ between pre and post measurement.

We also measured trust in the service, before and after the experiment. Figure 4 shows that, averaged over services, scores on the trust questionnaire for web services were higher after using the laptop than after using the iPAQ. The scores after the experiment for laptop users on the servitude ($Z(12) = 2.97$; $p < 0.01$), persistence ($Z(12) = 2.63$; $p < 0.01$) and trust ($Z(12) = 2.85$; $p < 0.01$) questions all differed significantly from the pre-measurement.

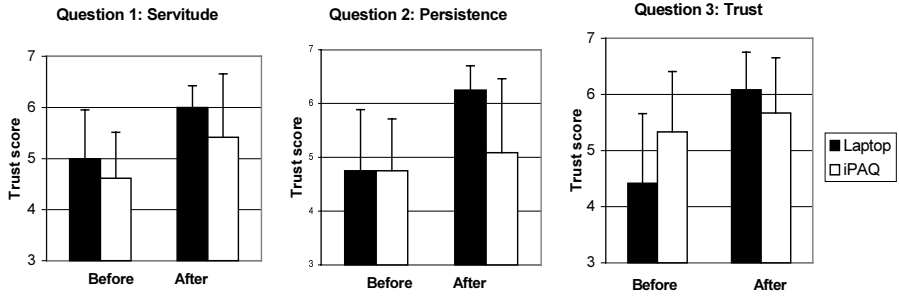

Fig. 3. Scores for trust in DEVICE, both before and after the experiment, for both devices separately. Error bars denote the standard deviation (SD)

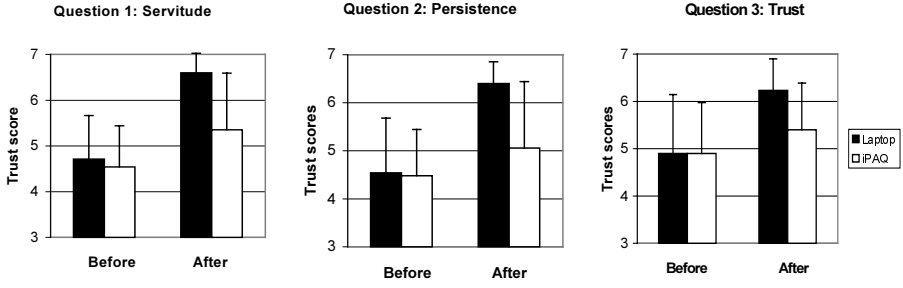

Fig. 4. Scores for trust in WEB SERVICES, both before and after the experiment for both devices separately. Error bars denote the standard deviation (SD)

3.2.4 Effects of Emotional State on Performance and Trust

No main effects of emotional state were found significant for any of the performance measures or any of the trust scores. The two way "emotional state x web service" interaction effect was found significant for time on task ($F(9, 153) = 3.64$; $p = 0.000$) and number of links ($F(9, 153) = 3.24$; $p = 0.001$). It appeared that performance was worse in the high arousal, positive valence condition for the Yellow Pages service. For trust in web services, the "emotional state x web service" interaction effect approached significance: ($F(9, 198) = 1.72$; $p = 0.086$). Again, on the Yellow Pages service, lower trust scores were obtained in the high arousal, positive valence condition. This corresponds nicely with the analysis of the performance measures.

In addition, a three way interaction of "device x emotional state x web service" was only significant for time on task ($F(9, 153) = 3.84$; $p = 0.000$). Time on the Yellow Pages service using the iPAQ was significantly higher in the high arousal, positive valence condition (258 sec.) than in the rest of the conditions (average 172 sec.).

There were no significant main effects on HR during work with the web services. However, a "device x web service" interaction effect was significant ($F(3, 63) = 10.30$; $p = 0.000$). It turns out that when using the book service and stocks service, HR is higher in the laptop condition (76.1 and 76.3 bpm respectively, compared to 73.4 averaged). HR is not significantly different between tasks in the iPAQ condition.

3.2.5 Multiple Regression

In order to gain more insight into the relations between emotion, trust, performance and device, the following questions were assessed using standard stepwise multiple regression:

- Is performance predicted by emotion or by device?
- Is trust predicted by performance, emotion or device?

In answering the first question, the predictors included in the regression analysis are the SAM scores after the film, heart rate during tasks and device. This analysis was done for all performance measures separately. For time on task and answer on task, device explained 27% and 26% of the variance respectively. The variance explained for number of links and typing errors is rather low (6%). The analysis showed that lower performance accompanied the use of the iPAQ. Arousal after the film did significantly explain some variance in time on task, however the added value is low (1%).

To assess which factors predict trust, all performance variables, device and SAM scores after the film as well as heart rate during tasks were included in the analysis. It appeared that 39% of the variance was explained by two performance measures alone, time on task and answer on task. Long time on task and more wrong answers accompanied lower trust scores. In comparison, device explained only 2% of the variance in the trust scores. Table 3 lists the results of the multiple regression analysis.

Table 3. Results of the multiple regression analysis. Codes in the regression equation are between brackets in the first two columns

Dependent variable	Predictor	Cum. R^2	Regression equation
Time on task (TOT)	Device (DEV) Arousal (AR)	27% 27%	TOT = -25.83 + 0.52*DEV + 0.08*AR
No. of links (LIN)	Device	6%	LIN = -0.32 + 0.24*DEV
No. of typing errors	Device	6%	TYP = -0.65 + 0.25*DEV
Answer wrong (ANS)	Device	26%	ANS = - 0.78 + 0.50*DEV
Trust (averaged scores on the 3 trust questions)	TOT ANS Heart Rate (HR) LIN Device	30% 39% 42% 44% 46%	Trust = 8.95 - 0.55*TOT - 0.32*ANS - 0.19*HR - 0.20*LIN - 0.15*DEV

3.2.6 Emotional state after Task Performance

In order to investigate the effects of device used and task performance on emotional state, the arousal and valence scores after the film and after the tasks were compared. A repeated measures ANOVA with factors device, film, pre/post measurement was performed, and the neutral condition was excluded from the analysis. For arousal scores, only a main effect for film ($F(3, 60) = 3{,}84$; $p = 0{,}01$) is observed. No significant effects or interactions were found in this analysis. The same analysis was run for valence scores. Main effects are found for device ($F(1, 20) = 6{,}16$; $p < 0{,}05$), film ($F(3, 60) = 11{,}78$; $p = 0{,}000$) and pre/post measurement ($F(1, 20) = 8{,}79$; $p < 0{,}01$). Valence is more positive after using the laptop (1,5) than after using the iPaq (0,8).

4 Conclusions

In general the type of device proves to have a substantial effect on performance and trust (see Figure 5). As expected, task *performance* was worse for the iPAQ. Furthermore, an interesting effect appeared: users of the small, mobile device used more ('wrong') links to find the target information. Probably, users need an overview of possible links (navigation paths) in order to assess which link is appropriate. For a small device, part of the current navigation space is out of vision so that assessments are more difficult. In conclusion, there proves to be a real need to diminish the navigation space for such devices, which the PALS project is developing [3].

The experiment shows that the service itself *and* the type of device influence user's *trust* in the service. Corresponding to the theory, trust builds up during the interaction with services in the laptop condition. However, during the interaction with the mobile device trust hardly increases (note that the user tasks and service content are completely similar for the mobile and laptop device). The regression analysis shows that interaction performance affects trust, causing a lower level of trust for the small device. Based on these results, we expect that improving the performance, for example

with an attentive interactive display [11] and decreasing the navigation space [3], will also result in increased trust. It is interesting to note that our results fit with the distinction of two levels of trust in design [9]. At the first level, the user forms a sense of trust based upon appearance only. Subsequently, as the user begins to interact with a product's explicit as well as implicit functionality, a sense of experiential trust is established.

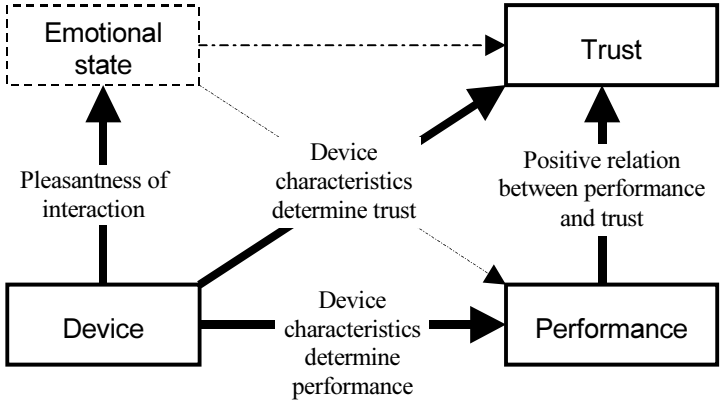

Fig. 5. The relations between trust, performance, device and emotion that were demonstrated in this study. Dotted lines indicate relations that could not be demonstrated unequivocally. These relations need further investigation

In particular when accessing the information search service (Yellow Pages) with the mobile device, there were distinct decreases in performance in the high arousal, positive valence condition, compared to the other conditions. Subjects took up to 300% longer to complete work on the service then in the laptop condition. In addition, subjects reported a 70% increase in mental effort, compared to the laptop. In this condition, emotional state, device and information search interfere. Further research should investigate to what extent an aroused, positive emotional state influences searching for information.

Task performance with the mobile device resulted in a lower valence score than with the laptop. In other words, users experienced a more negative *emotion* with the mobile device. Similar to trust, this effect might be attributed to the decreased performance.

In our experiment, heart rate proved not to discriminate between device, but it did discriminate between services for the laptop (i.e. heart rate was higher for the Books and Stocks services in the laptop condition). Probably, a substantial increase in effort for the mobile device would hardly help the users to improve their performance level. Consequently, the users do not feel inclined to increase their effort as with data-driven task performance compared to resource-driven task performance [15]. The task demands for Books and Stocks services are higher and extra effort helps to realise an adequate performance level. In this way, PALS may profit from a 'smart' heart

rate sensor in order to attune the interaction to user's state changes that are caused by task demand fluctuations.

In summary, device and service proved to be the major factors that determine the user experience. The experiment shows a clear need to improve the mobile interaction with web services in order to establish an adequate performance *and* trust level. The results provide an empirical foundation for working out the PALS concept (among other things by attentive interactive displays and personalised navigation spaces [8]).

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