Time, Location and Interest: An Empirical and User-Centred Study

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ABSTRACT
The importance of context in meeting user information needs has gained increasing interest. When developing interactive information retrieval systems, we do need to consider how contextual information might be used to improve information retrieval. In this paper, we present a user-centred experiment that focuses on three potential context attributes. These are time, location, and user's interest. The experiment involved tasks using a scenario that would be suitable for mobile situations - one very promising area for the application of context information that can help to deliver personalised services. The scenario involves situations with local events such as jazz concerts and includes the use of a simplified map to help visualise locations. The effect of the three attributes and the interactions between them are analysed and discussed. The effects in most cases were considerable and data analysis showed statistically significant effects. The study shows that time, location, and interest matter to users in mobile situations. There appears to be a priority emerging in the relative importance of these attributes for the mobile user. Also, the results show high order interaction effects between the attributes.

Categories and Subject Descriptors
H.3.3 Information Search and Retrieval

General Terms
Documentation, Experimentation, Human Factors

1. INTRODUCTION
The motivation for this work is to investigate whether context information can be applied to help users retrieve more useful content. Contextual information describes aspects of users and their environment. More specifically, we model context as a selection of attributes that describe the user and the environment in which the user interacts with an information system in order to resolve an information need. The aim is to build information retrieval systems that can help to deliver useful, personalized content to mobile users. Our approach is user-centred and empirical.

Information Interaction in Context, IIiX, Copenhagen Denmark

Context has gained increasing interest in the research areas of information seeking and retrieval, ubiquitous computing, user modelling, artificial intelligence, and adaptive hypermedia amongst others. Context modeling aims to create a better understanding of the contextual structures that is necessary for more effective application of context in information systems. Although several context models and context-aware systems exist, there are few experiments that empirically investigate the nature of individual attributes, connections between attributes, and their effects on users' behaviours. Such investigations are desperately needed to better understand and model context and apply it more effectively.

This paper presents an experiment based on three such attributes - time, location, and user's interest - regarding its impact on user's perception of usefulness. We chose to apply the user-centric methodology of the *simulated work task scenario* [2] further adapted for a simulated mobile scenario with event content. This domain appears as a very promising and representative area for context-aware computing. The effects resulting from the attributes of our model were considerable and confirm the importance of context for an information system that aims to deliver personalised services to its users.

2. RELATED WORK
In the field of information retrieval, the level of interest in context is increasing. In a special issue, Cool and Spink [5] provide an overview to the various ways in which context relates to information retrieval. The two workshops on Context in Information Retrieval over the last two years [9,8] provide a platform for the discussion of ideas and applications about context and its use for information retrieval problems. The importance of context for ubiquitous computing has also been identified with a special issue on user modelling by Jameson and Krueger [10]. Recently, there has been increasing interest in context modeling [7]. The information seeking community in CoLIS 2005 [6] particularly investigated theoretical approaches for better understanding and modelling of context. Context modelling is motivated by a general need for theory about context and its structures that will consequently help in building better frameworks and more effective systems. A range of context models and context-aware systems exist [1, 13, 11, 14]. More empirical work is needed in order to find the context attributes that matter for specific information retrieval applications.

Contextual attributes may appear intuitive which can lead to false judgements about their importance. The validity of attributes do need testing, with regards to how strong and interconnected particular contextual attributes affect users in general, their judgements, and their decisions. Such investigations are needed in order to understand, model, and apply contextual information accurately as part of an information system.

A more general context model was introduced by Myrhaug and Göker [11]. This model divides the contextual spectrum into the five categories of environment context, personal context, task context, social context, and spatio/temporal context. In this study, we are going to investigate two of these categories in greater detail by testing the impact of three attributes on users' perception of usefulness (situational relevance). In this paper, we investigate this model using Borlund's simulated work tasks, as described in [2][1]. Since mobile computing is one of the promising areas for the application of context, we developed a simulated, mobile scenario as the basis for our tasks in which users rated content about entertainment events. Our results show strong effects of all context attributes and many interactions between them. The remaining sections of this paper are divided into the following: In section 3, we provide the background and the reasoning for our selection of these contextual attributes. Section 4 and 5 outline the experimental design, stimulus materials, and the procedure of the experiment. Section 6 presents the results followed by the discussion of the numerous effects in section 7. Conclusions and suggestions for future work are presented in section 8.

3. THE CONNECTION BETWEEN USER, CONTENT, AND CONTEXT

The context model described in [11] is kept general and categorises a large contextual spectrum into the five aspects of environment context, personal context, task context, social context, and spatio/temporal context. The model serves as a guideline that allows for application specific refinement. For this study, we chose to look closer into two of these aspects - the spatio/temporal context and the personal context. The application of personal context allow the model to be used for content personalisation. Based on this choice, we now focus and refine this context model in the light of both the user and the content. In section 3.1 and 3.2, we will discuss contextual requirements for mobile usage and two types of content that are particularly interesting in such an environment.

3.1 Usage Domain

The way in which people use an information system is important for the modelling of contextual attributes. A number of aspects appear especially relevant: 1) Being mobile is cognitively intense since users often perform tasks simultaneously to other tasks (e.g. checking messages while walking). This requires mobile applications to provide more adapted and more focused content. Users cannot spend as much attention to the mobile application as when they interact with a desktop application [12]. Contextual information can help to achieve this focus on essential and useful information. In a mobile situation, users' location is one intuitive context attribute. 2) Tamminen et. al. [15] identified that mobile usage is generally more spontaneous than desktop usage. Within a planned activity, users allow for spontaneous sub-activities. However, users' temporal and spatial flexibility is limited by these activities. This suggests to use time and location as potential context attributes. 3) Mobile devices can only provide a limited amount of content on their small displays which calls for more focused content provision. Considering users' interest in the adaptation process is therefore especially important in order to achieve this focus. This is also suggested by the wide application of users' interest within personalised information systems for content adaptation [14].

3.2 Content Domain

As well as the usage environment, the content is another important factor that has implications on the context model. We have selected a mobile computing scenario as a focus of this study. Two particularity interesting types of content when being mobile are entertainment events and geographic maps.

Event Content and its Special Features: We used the Reuters Kalends event corpus for this study. The collection consists of 10500 leisure time events divided in 39 topical categories. From this collection, we identified a number of interesting features that have potential implications for a context model: 1) Events usually occur in at least one place (e.g. a play in a theatre). This indicates that event content has a strong connection with location. The relation between the user's current location and the event venue has potentially a strong influence on the usefulness of an event. 2) Also, events usually occur at least one time (e.g. a book signing event by the author of a novel in a local bookshop). They can be planned in advance. There are many similarities between event content and news content. However, news content mostly describes incidents in the past that are reported afterwards. Based on that, event content can be associated with a particular time or time period. Furthermore, events can be planned and predicted. This indicates a strong connection between event time and current time with potential influence on the usefulness of the event content. 3) Each event of the Reuters Kalends collection always belongs to exactly one of Reuters' topical categories. There may be a connection between these categories and the users' interest. For this reason, event categories could be matched with the personal interest of individuals. The existence of such a match would likely increase the usefulness of this event for this user.

Map Content and its Connection with Events: Geographic maps have two interesting aspects that connect them with event content: 1) Map content allows for *spatial integration* of event content since events are usually attached to at least one geographic location. This means that an event can always be plotted in a map. 2) *Temporal integration* of event content is also possible since an event has at least one particular performance time. Such methods, that integrate maps with time dependent map features, are still early in development with only few initiatives such as TimeMap (`http://www.timemap.net`). Besides these two major reasons, maps provide intuitive visualisation allowing users to explore content spatially as an extension to the traditional way of text.

[1] For reasons of simplicity, we will call them tasks.

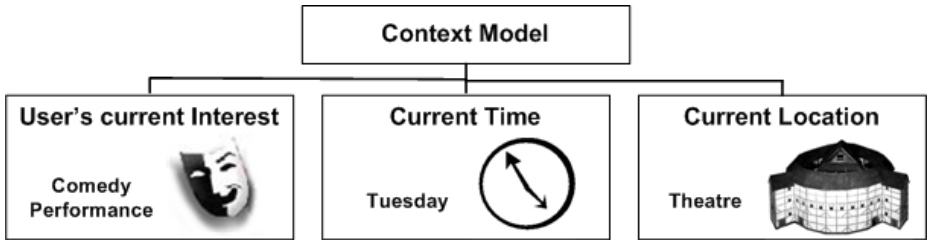

Fig 1. Example of one instance of the context model with the three attributes for user's current interest, current time, and current location as provided to participants.

Based on the considerations of the specific usage and content domain, we propose the context model as it is depicted in figure 1. This model consists of a promising set of relevant attributes based on the domain we have chosen for this experiment.

The model contains the three attributes which are *location*, *time*, and *interest*, as discussed above. These attributes have originated from two of the five broader contextual categories suggested in [11] and confirmed by a closer look into the special requirements that emerge from our usage and content domain. This model covers the user's personal context with one attribute (*interest*) and the spatio/temporal context with two attributes (*time* and *location*). These three contextual attributes are expected to influence the usefulness of geographically related event content in a mobile scenario. With these in mind, the following **four research hypotheses** emerge:

- H_1: Time has an effect on users' perception of event usefulness.

- H_2: Location has an effect on users' perception of event usefulness.

- H_3: Interest has an effect on users' perception of event usefulness.

- H_4: Time, Location, and Interest interact with each other regarding users' perception of event usefulness.

We are not suggesting these attributes to be finite or absolute. More and different attributes could have been proposed, such as the season of the year, the financial budget of the user, or various aspects of users' physical or psychological states. However, we assume that these attributes provide a reasonable set. The focused choice of attributes allows for a full investigation of all their effects. In future work, more attributes could be studied and combined with this basic set.

Although the context model is strongly motivated by mobile usage, we would like to point out that this model may also be applied in non-mobile usage scenarios. However, we expect that a mobile environment offers a higher challenge and a better utility for the attributes.

4. EXPERIMENT DESIGN AND METHOD

To investigate the four hypotheses about the main effects of the three attributes and their potential interactions, a repeated-measures experiment with a full factorial design was applied. Participants[2] in repeated-measures experiments perform in a range of experimental conditions (also called treatments). Since this removes natural differences between participants, it allows high statistical power to be obtained even from relatively small and moderate sized samples.

4.1 Experiment Setup and Scenario

For this experiment, we applied simulated work task situations [2] in order to establish an informative environment that helps participants to create information needs and provides them with a framework for their judgements. Each participant received a background scenario together with a list of contextual situations. Whereas the background scenario described the broader setting of the experiment, the situations represented more detailed information. We decided to present the background scenario as a festival - a typical "hotspot" for entertainment events of all kind.

Festivals as Event "Hotspots": During festivals, large varieties of events for leisure time entertainment are provided. Activities and performances usually run within a relatively short period of time. Event locations are usually held within a shorter distance; most likely an dedicated area or a small number of places that provide appropriate space, facilities, and general infrastructure. The Aberdeen Jazz Festival 2006 for example ran over five days, providing a total of 30 performances at five different venues close to the city centre. The much larger Edinburgh International Festival is usually held over two weeks at a few main (and some additional smaller) venues.

Background Scenario and Contextual Situations: To create an equally realistic setting for our tasks, we chose a small fictional festival as a background scenario with a small set of events about *Jazz Music* and *Comedy Performance* distributed over a time of three days (*Monday*, *Tuesday*, and *Wednesday*). In this scenario, events are performed at three different fictitious places (the *Theatre*, the *Community Centre*, and the *Gallery*) located along a long street next to each other. All locations were only accessible by walking. To support the scenario visually, each user also received a paper map with the event locations. The choice of values for time, location, and interest were based on the following considerations:

- *Time*: We chose to select three days of the working week instead of the weekend in order not to create any bias towards or against particular days. Saturdays tend to be more popular for entertainment and socialising than other days which could skew the experimental data. Although an event festival on

[2] In this paper we use the term 'participant' and 'user' interchangeably, since we obtain results from an experiment but with the aim to apply these findings in a mobile usage environment.

weekdays might cause generally lower rates of usefulness, it will ensure stable results.

- *Location*: The background scenario is more general and does not refer to any particular town. The three chosen locations resemble three generic locations that exist in most towns. This was necessary in order to obtain results that are not bound to one particular city but instead support generalisation. It also solves the problem that participants do not need any specific knowledge about a town and particular places in order to participate in the experiment.

- *Interest*: In real life, peoples' interest is a very personal and dynamic variable. Since we chose to investigate interest as one of the attributes, it was necessary to control its variation as part of the experiment. The two kinds of interest (*Jazz Music* and *Comedy Performance*) were inspired from the Reuters Collection. Both types of interest are distinct enough to allow participants to differentiate them clearly.

Event Calendar: Participants also received an event calendar with four different events that were extracted from the Reuters Kalends event collection. The content for each event consisted of a title, a short description, performance time, venue, and the interest category. The event titles and descriptions were taken from Reuters' collection. The event performance time was one of the evenings of the three days (*Monday*, *Tuesday*, or *Wednesday*) and the event location was one of the three places (*Theatre*, *Community Centre*, or *Gallery*). Two of the events were about *Jazz Music* and two were *Comedy Performance*. In a real festival, this material could be handed out to people as part of an information brochure that describes the basic outline of the highlights together with a detailed account of the programme.

Eighteen different contextual situations (i.e. 3 possible times x 3 possible locations x 2 possible interests) were given to each participant. A situation is comprised of one of each of these attributes. Time being either *Monday*, *Tuesday*, or *Wednesday*, location being either at the *Theatre*, at the *Community Centre*, or at the *Gallery*, and personal interest being either *Jazz Music* or *Comedy Performance*. The example in figure 1 shows one situation where the participant, located at the Theatre on a Tuesday, is interested in Comedy Performance.

5. EXPERIMENT PROCEDURE

The background scenario, contextual situations, and the event calendar, as described in section 4.1, was explained and handed out to participants. They were asked to rate the usefulness of the four different leisure time events in relation to the 18 different situations. In preparation for the task, users were introduced to usefulness as situational relevance. According to Borlund, situational relevance "...expresses the relationship between the user's perception of usefulness of a retrieved information object, and a specific work task situation" [3]. The situations contained information about the current time, the current location, and the current focus of interest. Each situation was embedded in the festival scenario as it was described in the last section. For all these situations, participants were required to rate the usefulness of each event. The rating was scaled along a 6-point rating scale that was ranging from 1 ("Not at all") to 6 ("Very much"). The scale forced a decision from participants based on the missing middle score. The order of situations was randomised to eliminate ordering effects. The participants for this user study were 32 individuals chosen from the student and staff population of the Robert Gordon University in Aberdeen/Scotland. They were 20 to 49 years old (75% were 18 to 29 years), 14 male and 17 female.

6. RESULTS

In this section, we provide an overview to the data, a graphical representation of contextual effects, and a table with the degrees of statistical significance and corresponding effect sizes.

6.1 Data Overview

The participants provided ratings of usefulness for event content based on a set of situations that were defined along time, location, and interest.

For each user rating, we calculated the differences between the time of the situation and the event performance ($time_{situation}$ - $time_{event}$), the location of the situation and the event venue ($location_{situation}$ - $location_{event}$), and determined if there was a match or a non-match between the interest of the situation and the event interest category. This resulted in 5 possible differences for Time (-2, -1, 0, 1, or 2 days of difference), 3 possible distances for Location (0, 1, or 2 places of distance), and a binary possibility for Interest being either matching (0) or non-matching (1).

Figure 2 shows the magnitude and change of all Time (T), Location (L) and Interest (I) effects graphically on the mean event usefulness as it was rated by participants. The graph shows the mean usefulness (average rated values of usefulness) assigned by participants for matching interest (I = 0) in the upper part of the graph and for non-matching interest (I =1) in the lower part of the graph. The error bars indicate standard errors.

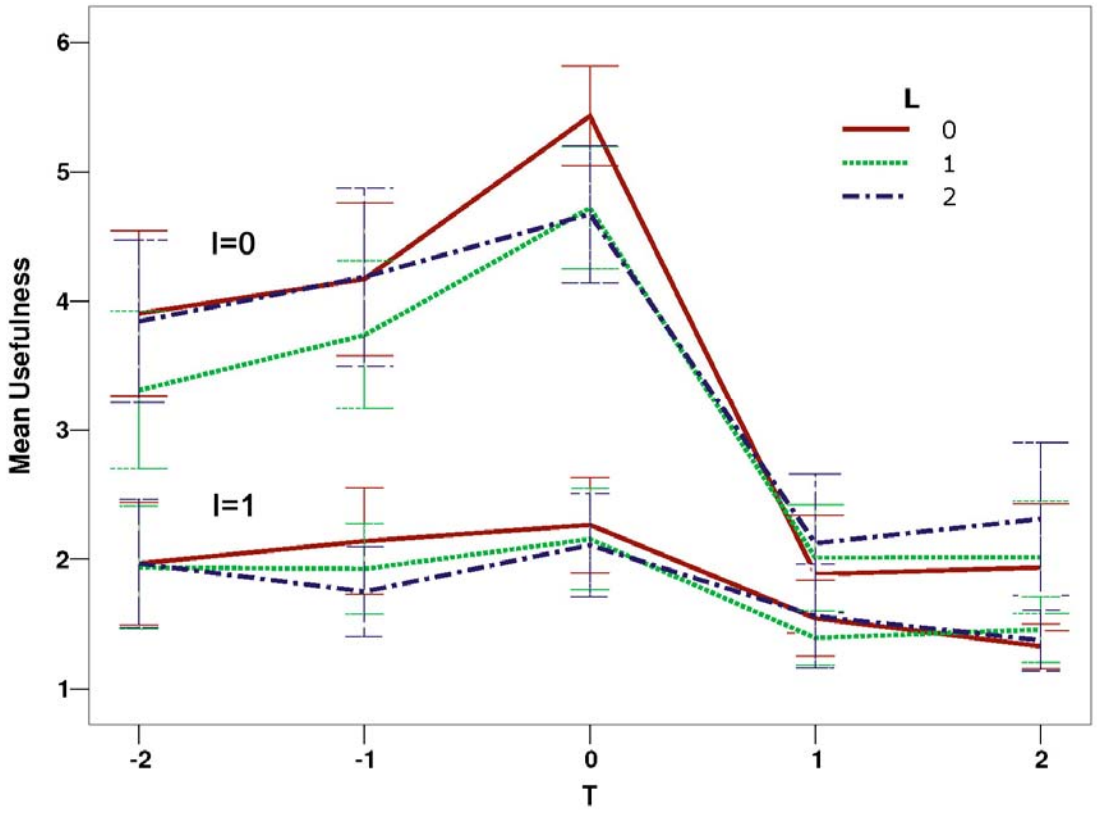

Fig 2. Mean rated usefulness for matching interest (I=0) and non-matching interest (I=1) for 5 levels of Time (T) and 3 levels of Location (L)

As mentioned before, we study 5 differences for time, 3 distances for location, and a binary interest being either matching or non-matching. The time levels (T-Levels) are provided in days and 4 different level changes are possible between the 5 distinct time differences. Similarly, the location attribute provides two different level changes (L-Levels) from 0 to 1 and 1 to 2 places of difference. The interest attribute can only change from matching interest (0) to non-matching interest (1) which means that the repeated contrast is equal to the overall effect of interest (I-Levels). The interaction between location and interest (L x I) is statistically not significant and contrasts are therefore not provided.

Table 1. ANOVA results with contrasts for time (T), location (L), interest (I), and their interactions. Statically significant effects are labelled with asterisks (*).

Effect	T-Levels (difference in days)	L-levels (difference in places)	I-levels (match)	F	effect (η^2_p)	sig.
T (overall)				**38.299**	**.553**	**.000***
T(contrasts)	-2 → -1			2.957		.095
	-1 → -0			28.185		.000*
	0 → +1			81.991		.000*
	+1 → +2			0.128		.723
L(overall)				**3.872**	**.111**	**.042***
L(contrasts)		0 → 1		9.495		.004*
		1 → 2		5.459		.026*
I				**95.388**	**.755**	**0.00***
TxL(overall)				**3.379**	**.098**	**0.07***
TxL(contrasts)	-2 → -1	0 → 1		0.006		.939
		1 → 2		0.406		.527
	-1 → -0	0 → 1		0.372		.546
		1 → 2		1.332		.257
	0 → +1	0 → 1		9.502		.004*
		1 → 2		1.518		.227
	+1 → +2	0 → 1		2.362		.135
		1 → 2		0.056		.814
TxI(overall)				**26.497**	**.461**	**0.00***
TxI(contrasts)	-2 → -1		0 → 1	3.513		.070
	-1 → -0		0 → 1	12.264		.001*
	0 → +1		0 → 1	63.717		.000*
	+1 → +2		0 → 1	8.641		.006*
LxI(overall)				**2.217**	**.067**	**0.139**
TxLxI(overall)				**2.420**	**.072**	**.049***
TxLxI(contrasts)	-2 → -1	0 → 1	0 → 1	1.343		.255
		1 → 2	0 → 1	0.077		.783
	-1 → -0	0 → 1	0 → 1	2.845		.102
		1 → 2	0 → 1	3.596		.067
	0 → +1	0 → 1	0 → 1	8.817		.006*
		1 → 2	0 → 1	0.041		.841
	+1 → +2	0 → 1	0 → 1	1.596		.216
		1 → 2	0 → 1	4.922		.034*

6.2 Detailed Account on Context Effects

The ANOVA results and relevant repeated contrasts for the main effects of time (T), location (L), interest (I), and their interactions (T x L, T x I, L x I, and T x L x I) are listed in table1. Contrasts provide statistical significance between individual factor levels. The table provides only contrasts for statistically significant overall effects ($p<.05$). In other cases, contrasts are not statistically significant and are therefore not listed. For that, the table lists the F-values (F) and the p-values of statistical significance (sig). The p-values of overall effects are corrected by the Greenhouse-Geisser method since the data did not provide equal differences between treatments levels - quite common when using factors with more then two levels. Furthermore, the table provides effect sizes for all main effects and interactions (expressed in the common partial eta squared measure (η^2_p). Effect sizes express the strength of an attribute or an interaction in relation to the rated usefulness.

Based on the ANOVA table, we now discuss the effects caused by the attributes of our model. We will frequently reference their appearance in the users' ratings as depicted in figure 2.

- The effect of **time** on the judgement of usefulness (T) has high statistical significance ($p<.001$) and an effect size of $\eta^2_p=.553$. The contrasts show that significant effects only exist for the time difference between the day before and the same day as well as between the same day and the day after the event. These two changes can be seen as a strong rise directly before the day of the event and a very sharp decline after the event performance in figure 2 although much less pronounced with non-matching interest (I=1).}

- The effect of **location** (L) is also statistically significant ($p<.05$) and its contrasts confirm this between each level pair. The effect size of location is of smaller magnitude ($\eta^2_p=.111$) in comparison to time and interest. When viewing the graph, the effect of location can be seen as the distance between the individual lines. Each of the lines represents the change of usefulness over time at one location.

- The effect of **interest** (I) also revealed to be highly significant with p$<$.001 and the strongest of all main effects with $\eta^2_p=.755$. This can be viewed in the graph when comparing the upper part of the graph (I=0 or matching interest) with the average ratings visualised in the lower part of the graph (I=1 or non-matching interest).

Further, there is rich interactive behaviour between all three contextual attributes:

- The **three-way interaction between all three factors** (T x L x I) showed up statistically significant with $p<.05$ and an overall effect size of $\eta^2_p=.072$. Its contrasts are statistically significant in two cases. The first interaction ($p<.05$) exists between the same day and one day after the event when the location difference changes from the same place to one place and matching interest changes to non-matching. In this case, matching interest causes a stronger decline in usefulness in comparison to non-matching interest. This effect can be viewed graphically when comparing the two groups of lines in figure 2 . Whereas for matching interest (I=0) the difference between matching place and one place difference collapses shortly after the event, for non-matching interest (I=1) it remains almost constant. The second interaction occurs at the end of the curve between one day and two days after the event where the usefulness rises for interested users being two places away from the venue but not for those whose interest does not match.

- The **two-way interaction between time and location** (T x L) is statistically significant with with $p<.05$ and an effect size of $\eta^2_p=.098$. The contrasts show significant interactions when time changes from the same day to one day after and the location difference from the same place to a one place difference.

-The **two-way interaction between time and interest** (T x I) is statistically significant with $p<.001$ and shows in almost all cases statistically significant interactions. It also represents the strongest interaction effect with $\eta^2_p=.461$. When participants time context changes from one day before to the matching day, the usefulness rises faster when interest is met then when interest is not met. The opposite happens shortly after the event when the time context changes from the matching day to one day after. In this occasion, usefulness declines much stronger when users' interest was met in comparison to the case when users' interest is not matching. Also there is a statistically significant interaction at the end of the time line when the location changes from one place to a two place distance and matching interest changes into non-matching.

There is no statistically significant interaction between location and interest (L x I) as a directly result of our experiment. Consequently, contrasts for this interaction are not included in table 1. Although not significant in the strict sense, there seems to be a trend for the existence of interactive behaviour between location and interest. However, the effect size is consistent with the significance level indicating only a very small effect imposed by this interaction. We are aware that such an interaction might exist in other experimental settings that involve users' knowledge and long term behaviour.

7. DISCUSSION

We conducted this user study to obtain a better insight into contextual attributes and their effects on people. In particular, we tested the following four hypotheses in order to investigate the impact of three carefully selected context attributes on users' perception of usefulness (or situational relevance as described in [3]).

-H_1: Time has an effect on users' perception of event usefulness.

-H_2: Location has an effect on users' perception of event usefulness.

-H_3: Interest has an effect on users' perception of event usefulness.

-H_4: Time, Location, and Interest interact with each other regarding users' perception of event usefulness.

The study was focused on event content with geographic relevance since we decided for a setting that is relevant for mobile computing.

All three attributes revealed statistically significant effects. It also turned out that all three context attributes have high order interaction effects between them. In the following, we discuss all context attributes and contextual interactions based on the order of our hypotheses:

-**Time** caused an overall large effect on users' perception of usefulness. The attribute was expected to cause higher degrees of usefulness before the performance time of the event in comparison to the time after the event. Furthermore, its peak usefulness was expected to be when the time of the situation matches with the performance time of the event. These expectations are confirmed by the findings and show strong evidence for time having an effect on users' perception of usefulness (H_1). It is very interesting that the style with which event usefulness is rising and declining seems not to be linear. Between two days and one day before the event rising is much slower in comparison with one day before and the matching day. After the event, usefulness is declining very strong between the matching day and one day after the event. This continues between one day after and two days after the event, however in much smaller magnitude. This behaviour indicates a nonlinear effect of

time on event usefulness and is confirmed by the shape of the data at every location and interest level.

-Location showed statistically significant effects on the amount of usefulness (H_2). However, the attribute has generally a much lower impact than the other attributes. This is both indicated by the weaker level of statistical significance as well as the associated effect size. One reason for this can be the distances between locations which have not caused much reason for participants to consider remote events much less useful. Also, the rather large time frame of several days must have caused location to be less influential when the event was still in the very far future. The structure of the effect of location is also interesting. The assumption was that people would favour an event being local in comparison with the same event being more distant. Location-aware systems generally work on this premise when extracting and processing information. This expectation can only be partially confirmed by the data. In cases where the user's interest is met and the event has not yet been performed, local events are rated highest. Usefulness drops when the distance to the event location increases by one place in this condition. However, events that have the maximum distance surprisingly increase again in their usefulness instead of dropping. After the event performance, the effect of location is actually reverted in respect to the original expectation. Events at maximum distance are rated highest and at the current location lowest. When the user's interest is not matching the event, the effect of location follows the normal pattern (further distant implying less useful). However after the event, this is not the case. One obvious reason for this must be that the event location has more relevance before the event than after. This has potentially also caused the rise of usefulness between one and two places of distance. Users might have paid only limited or no attention on the precise quantitative rating after the event because of its low use. This shows evidence for a strong connection of location with the other two attributes; particularity with time.

- **Interest** has a profound effect on users' rating of usefulness (H_3) indicated by the largest of all effect size. Matching interest produced a strong rise of usefulness indicating the intense impact of the attribute on users' opinion. This confirms with the literature, in which interest was frequently used as one of the main attributes for content personalization [4].

- As already described in the last three points, we have obtained comprehensive statistical evidence about strong and manifold **interactions between all three attributes** in almost all cases (H_4). The data confirms a very strong interaction between time and interest as well as smaller interactions between the other two-way as well as the three-way interaction. This clearly indicates that we cannot derive a model of context by the simple combination of time, location, and interest. It is necessary to include the interactive behaviour between the attributes. The strong connectivity between this rather focused set of attributes shows an example of how complex a context model can evolve with only three components.

8. CONCLUSIONS AND FUTURE WORK

Starting from a broader and more general context model, we investigated three promising contextual attributes - time, location, and interest - based on their impact on users' perception of usefulness. Since mobile computing (e.g. as in location-based services) is one very promising application area for context, we evaluated our four hypotheses along a simulated, mobile scenario as the basis for a task in which users rated content about entertainment events. The impact caused by time, location, and interest was considerable and confirmed the validity of the attributes as part of the chosen context model. Interest has the strongest effect on users' perception of usefulness followed by the time attribute. The effect of location is weaker, ranking after the interaction of time and interest. We conclude that location generally has a much lower impact than commonly assumed. All remaining interactions have statistically significant effects of smaller magnitude. This study has provided an insight into the dynamics of a context model along a relevant and promising scenario for the application of context. This allows us to describe the relation between context and perceived usefulness in a much more precise form. The chosen attributes show evidence to be useful in the information retrieval process to help users receiving more personalised and focused results from a mobile information system.

As a next step, we will formulate a functional relationship between usefulness and the three attributes of our model. This allows us to predict the usefulness of an event content item, based on the user's current situation and expressed by a contextual score. We will apply this in a mobile system to personalise search results based on contextual conditions through the combination of our context score with the score of an information retrieval system. This is expected to amplify traditional searches into personalised searches that deliver results based on the individual, contextual situation of a user. Most importantly, the application of our findings will enable us to verify our results in a realistic setting with mobile users.

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9. REFERENCES

1. ABOWD, G. D., ATKESON, C. G., HONG, J., LONG, S., KOOPER, R., AND PINKERTON, M. Cyberguide: A mobile context-aware tour guide. *Wireless Networks 3*, 5 (1997), 421– 423.
2. BORLUND, P. Experimental components for the evaluation of interactive information retrieval systems. *Journal of Documentation 56*, 1 (2000), 71–90.
3. BORLUND, P. The concept of relevance in ir. *Journal of the American Society for Information Science 54*, 10 (2003), 913–925.
4. BRUSILOVSKY, P. Adaptive hypermedia. *User Modeling and User-Adapted Interaction, Ten Year Anniversary Issue(Alfred Kobsa, ed.) 11*, 1-2 (2001), 87–110.
5. COOL, C., AND SPINK, A. Special issue on context in information retrieval. *Information Processing and Management 38*, 5 (2002), 605–611.

6. CRESTANI, F., AND RUTHVEN, I. Context: Nature, impact, and role. In *5th International Conference on Conceptions of Library and Information Sciences (CoLIS 2005)* (Glasgow, UK, 2005), Springer Verlag.
7. INDULSKA, J., AND ROURE, D. D. Workshop on advanced context modelling, reasoning and management. In *6th International Conference on Ubiquitous Computing (UbiComp 2004)* (Nottingham, England, 2004).
8. INGWERSEN, P., JAERVELIN, K., AND BELKIN, N. Workshop on information retrieval in context. In *28th Annual International ACM SIGIR Conference on Research and Development in Information Retrieval* (Salvador, Brazil, 2005), Royal School of Library and Information Science, Copenhagen, Denmark.
9. INGWERSEN, P., RIJSBERGEN, K. V., AND BELKIN, N. Workshop on information retrieval in context (irix). In *27th Annual International ACM SIGIR Conference on Research and Development in Information Retrieval* (Sheffield, UK, 2004).
10. JAMESON, A., AND KRUEGER, A. Special issue on user modeling in ubiquitous computing. *User Modeling and User-Adapted Interaction* (2005), 193–338.
11. MYRHAUG, H. I., AND GOKER, A. Ambiesense - interactive information channels in the surroundings of the mobile user. In *2nd International Conference on Universal Access in Human-Computer Interaction* (Crete, Greece, 2003), vol. 4, Lawrence Erlbaum Associates, pp. 1158–1162.
12. OULASVIRTA, A., TAMMINEN, S., ROTO, V., AND KUORELAHTI, J. Interaction in 4- second bursts: The fragmented nature of attentional resources in mobile hci. In *International Conference for Human-Computer Interaction (CHI)* (Portland, Oregon, USA, 2005), ACM Press, pp. 919–928.
13. RYAN, N. S., PASCOE, J., AND MORSE, D. R. Fieldnote: A handheld information system for the field. In *1st International Workshop on Telegeoprocessing* (Lyon, France, 1999), Kluwer Academic Publishers, pp. 156–163.
14. SETTEN, M. V., POKRAEV, S., AND KOOLWAAIJ, J. Context-aware recommendations in the mobile tourist application compass. In *3rd International Conference on Adaptive Hypermedia and Adaptive Web-Based Systems (AH2004)* (2004), W. Nejdl and P. D. Bra, Eds., Springer Verlag, pp. 235–244.
15. TAMMINEN, S., OULASVIRTA, A., TOISKALLIO, K., AND KANKAINEN, A. Understanding mobile contexts. *Personal and Ubiquitous Computing 8*, 2 (2004), 135–143.