# When More is Less: Designing for Attention in Mobile Context-Aware Computing

## Exploring a Context-Aware Shopping Trolley



Darren Josef Black
Nils Jakob Clemmensen


Master's Thesis in Computer Science
(Human-Computer Interaction)


Aalborg University


Spring 2006

AALBORG UNIVERSITET

Department of Computer Science
Frederik Bajers Vej 7e
Dk9220 Aalborg
Denmark

**TITLE**

When Less is More: Designing for Attention in Mobile Context-Aware Computing

**PROJECT GROUP**
d613a

**GROUP MEMBERS**
Darren Josef Black
Nils Jakob Clemmensen

**COUNSELLOR**
Mikael B. Skov

**SEMESTER**
INF8

**PERIOD:**
1/2-2006 til 8/6-2006

**NUMBER OF COPIES**
6

**TOTAL NUMBER OF PAGES**
21pp + 23pp (appendices)

**APPENDICES**
*"Drawing Attention to Context-Awareness with CaST: A Context-Aware Shopping Trolley"*,
*"Reducing Task Complexity by Dividing Attention: Exploring a Context-Aware Shopping Trolley"*,
Data from evaluation:
www.cs.aau.dk/~njay/appendices.rar

**ABSTRACT**

This master thesis documents the research, design, and evaluation of a context-aware system which actively acquires user attention.

Based on the results of an ethnomethodological study of supermarket shopping we design and implement a Context-Aware Shopping Trolley (CaST) that aims at lowering the complexity of supermarket shopping for its users. An extensive evaluation was carried out during the span of one week, where 18 participants took part in a field experiment in a Føtex supermarket. These participants were split into two groups. This yields the following results of how the implemented prototype of CaST supports shopping:

Users of CaST travelled a significantly short distance compared to users with shopping lists

CaST users generally collected the products in the same order which the shopping list users did not

In their subjective workload assessment CaST users reported a significantly lower mental workload compared to the shopping list users.

Based on these results we conclude that CaST lowered the complexity of the shopping task.

## Preface

This report is the product of a two semester master thesis. The result of this work consists of this report and two research papers (located in the Appendices section). One paper concerns how a context aware shopping trolley (CaST) can be designed to acquire attention and the other describes how the CaST prototype supported the shopping activity. We strongly urge the reader to read both the report and both papers.

## Disclaimer

We would like to note that while the Føtex supermarket in which this project is based is often depicted as being a troublesome environment for shoppers, this should **not** be interpreted as criticism of the store. The issues raised can be found in any supermarket.

## Acknowledgements

We would like to thank a number of people, without whom this project would not have been possible. First and foremost, we would like to thank the staff and management of the east Aalborg branch of Føtex for their time, enthusiastic interest, co-operation and grilled burgers. We would also like to thank Ph.d student Rune Thaarup Høegh for offering useful advice and views, and Staffan Nielsen for numerous timely Photoshop efforts for no personal gain. It‘s great when people just want to help out. We would also like to thank the many people who gave us their time over the past year to take part in our numerous experiments and tests. Last, but by no means least, we would like to thank our supervisor Mikael Skov for his useful guidance over the course of the last year.

Darren Josef S. Black

_______________________________

Nils Jakob Clemmensen

_______________________________

Contents

# When More is Less: Designing for Attention in Mobile Context-Aware Computing

## Introduction

New technologies are often blamed for adding complexity to our lives; time and again we hear people yearning for a return to ‗simpler times'. This was a time before mobile phones, MMS', PDAs, Bluetooth-enabled sunglasses and Podcasting. There is admittedly some inherent truth to this since, by the very definition of the word, the more things there are in our lives to deal with, the more complex our lives are. We wonder, however, whether the introduction of technologies can actually reduce the complexity of some of the tasks we perform, despite being ‗yet another gadget' to interact with.

In recent years there has been great progress in mobile technology, and it is arguably mobile technology that contributes most to the perceived technological invasion into our lives.  After all, since stationary technologies stay put, we can escape them and the extra complexity they impose on us. Conversely, mobile technologies follow us around, so to speak.

### Mobile devices

There exists a great deal of documented research on the use of, and effects of the use of, mobile systems in various fields. Mobile systems have been found to effect task performance, often in a negative manner. This effect can be seen in the numerous studies of mobile telephone usage in driving situations. The use of a mobile phone with hands-free functionality has been shown to increase the risk of accident in car following situations [1].  Statistics from Japan indicate that mobile phone use was associated with an average of 2303 car crash-related injuries per year from 1997-1999, and an average of 24 deaths per year over the same period [2].

### Context Aware Mobile Systems

Returning to the topic of technology-induced complexity, the past decade has seen a great deal of research in the field of context-aware and ubiquitous computing.

–One of the major research directions for human-computer interaction (HCI) over the past few years has been exploring the novel forms of interaction that can be achieved by integrating computer technology with the everyday physical world in which we live and work. This line of research goes by a number of names—

ubiquitous computing, context-aware computing, pervasive computing, embodied interaction, and more.‖ [3]

The realisation of these concepts promises to reduce the complexity of our lives once again by making computers ‗invisible' – by sensing the user's context and using rules of inference these systems autonomously update to provide the user with information and services he/she will find useful. This notion of invisibility is perhaps best surmised by the man often viewed as the father of the ubiquitous computing movement, Mark Weiser:

*"A good tool is an invisible tool. By invisible, I mean that the tool does not intrude on your consciousness; you focus on the task, not the tool." (Weiser in [4])*

The aforementioned progress in technology has yielded a great number of mobile context-aware systems but the application of these is a young science. The notion of context-awareness was first introduced in the mid nineties in research conducted at the Xerox Palo Alto Research Center. During his attachments to Xerox PARC, Schilit together with Theimer wrote the first recognised description of context-aware computing, a work that have afterwards been seen as the foundation of context awareness on which a plethora of articles have now been written. In the aforementioned article Schilit and Theimer wrote this definition of context-aware computing:

*"Context-aware computing is the ability of a mobile user's applications to discover and react to changes in the environment in which they are situated."*

This definition of context awareness is still operational although other scientists have added to or altered it to fit more applications of use. Going further than just defining context-aware computing, Schilit and Theimer also defines three aspects of context that are relevant for context-aware computing:

*"<u>Computing environment</u>: available processors, devices accessible for user input and display, network capacity, connectivity, and costs of computing*
*<u>User environment</u>: location, collection of nearby people, and social situation*
*<u>Physical environment</u>: lighting and noise level"*
Data from these contexts could, according to Schilit and Theimer be used in computing to create new types of user-beneficial applications. Since Schilit's and Theimer's early work, perhaps due to the appeal and novelty of the concept, research on context-aware technologies has grown massively.

A prototypical example of a context-aware mobile system is the GUIDE project, produced at Lancaster University [6]. This project involved the deployment of an information system designed to help tourists in the city of Lancaster. The system provides users with information, pictures and audio related to attractions and sites in the city depending on their location. Their initial approach to the task utilised the more traditional approach to interaction termed ‗information pull' – users had to manually instruct the system to provide them with information (in much the same manner as the World Wide Web functions). A later revision of the system would use an ‚information push‘ approach.

Lonsdale et al. [7] describes a museum guide system that uses ultrasound to gather positioning data, which is then used to help the user navigate on a small screen device. The system also uses positioning data to calculate the proximity to nearby pieces of art, which it uses to find out whether or not the user‘s attention is on any particular item. Should this be the case, relevant information on that particular piece of art will be shown on the user‘s device. Longsdale et al. [7] is an example of how context awareness can be used to enhance the user‘s experience.

## Attention in Context-Aware Systems

Returning to Weiser‘s vision of ubiquitous computing, he is cited as describing ubiquitous computing as *"that which informs but doesn't demand our focus or attention"*. We find this statement interesting, since it is unclear how one can be informed by something if that something does not have one‘s attention. In this vein, we have noticed a tendency in the literature of the testing of context-aware systems revealing what we interpret as attention-related issues. We believe we are seeing a tendency for the invisibility of these systems to work against their effectiveness. The autonomous updates which characterize context-aware systems often occur when the user‘s attention is away from the system. While this behaviour is in accordance with the nature of context-aware computing, these updates are often met with unexpected reactions by users.

For example, Skov and Høegh in [8] document the implementation and testing of a context-aware patient record system. The system provided hospital staff with information relevant to the patients in the room they were standing in. During evaluation, there were numerous instances of users looking at the system while in one room in the hospital, taking their attention away from the system and moving to another room. Upon arrival in the new room, the users looked at the system again. During this time, updates to the system‘s interface occurred. For some subjects this caused minor confusion, while for others, more serious problems occurred.

In a similar manner, Bohnenberger et al. (in [9]) describes the implementation and testing of a shopping mall guide system. The system works on a ‚macro‘ level, instructing the user which shops to visit, and in which order, to make their shopping activity more effective. The system achieved this goal using an extremely simple interface, which directed the shopper towards shops using arrows. In testing, users complained that the need to constantly attend to the system while navigating the mall was troublesome, but necessary – if they did not regularly look at the system they would miss updated directional cues.

Incidents similar to the ones described by [8] and [9] et al. can be described through definitions by Dey and Barkhuus [10]. In their examination of user control in context-aware systems Dey and Barkhuus define three levels of interactivity in mobile applications: personalization, passive context-awareness and active context awareness. Personalization pertains to manual customization based on personal preferences while active and passive context-awareness are respectively a system updating on behalf of the user (active context-awareness) and a system prompting the user before updating (passive context-awareness). To find out what users thinks of these three forms of interactivity, a five-day diary study with 23 participants was carried out. For the experiment the participants had to pretend that their mobile phones were capable of supporting both personalized and active/passive context-awareness services to aid them in 7 everyday scenarios. At the end of each day, each participant had to fill out a diary of how many times they would have used the services and to what degree they thought the services would have been useful. The resulting findings state that the participants generally preferred active context-awareness, even though this made them feel less in control.

The autonomous updates seen in the systems explored by Skov and Høegh and Bohnenberger et al. qualify them as being active context-aware systems. Looking at the problems experienced by the users of MobileWard and the context aware shopping guide, it appears that possible solutions to both systems‘ issues could be to make them passive instead of active with regards to context. Passive context-aware interaction could ensure that the users of the aforementioned systems would notice that the system had updated themselves, and by doing this alleviate the confusion caused by transparent updates. Another solution however, would be to draw attention to the system when it updated. This way the users could immediately be made aware that the system had updated and then react accordingly. Though more research is necessary to find out if the users of these systems would benefit from getting their attention drawn to the system, the notion that users of tool that according to Weiser should be invisible, could actually benefit if that tool demanded attention.

## Research Focus

To surmise the key points of the issues discussed:

- Technology is often seen as increasing the complexity of our lives by giving us extra things to attend
- Context-aware technologies purpose to reduce task complexity by sensing context and thus alleviating attentional demands
- There are cases where context-aware systems are ineffective due to lack of user attention on the system

Given these predicates, we are interested in exploring the possibility that some context-aware systems could benefit from actively acquiring attention, and in doing so, could reduce task complexity despite demanding attention. As such, our main research goal can be seen as attempting to provide an answer to the following question:

*"Can a context-aware system reduce task complexity by acquiring user attention, and if so, how, and under which circumstances?"*

Our approach to providing an answer to this question involves the design and implementation of an attention-acquiring context-aware system, followed by a field evaluation of that system.

We find an interesting case to study in the supermarket shopping domain. Aside from being a necessary chore, supermarket shopping is of interest to our research since it takes place in a rich, complex environment. Some find this environment pleasant while others get stressed and even feel physical discomfort from being exposed to factors such as heat, crowding, noise and the visual assault from thousands of products [11]. Regardless of how one reacts to this environment, all the elements present compete for attentive resources, just as speech from mobile phones compete with visual attention on the road in a driving situation.

Corresponding to our approach described previously, we aim to provide answers to the following two research questions:

1) ―How can we design a context-aware shopping trolley to acquire user attention?‖

2) ―How can an attention-acquiring, context-aware shopping trolley support the shopping activity?‖

The results of the evaluation of the system will lead to a discussion of what characterizes the supermarket shopping context, and a comparison to other use contexts.

## Case: A Context-Aware Supermarket Application

In order to design a context-aware system for the shopping, it is necessary to explore how complexities in this environment affect the shopping activity.

### Field Experiment at Føtex

A field experiment in the form of an ethnomethodological study (for an explanation of this approach see [12]) was carried out in a Føtex supermarket, a part of the Føtex-chain (mid-sized supermarkets). The store in which our experiment was conducted is approximately 30.000$m^2$ consisting of a bakery, a fast food restaurant, a kiosk and various facilities for the staff. The retail area itself is approximately 20.000$m^2$ divided into areas where a large assortment of different products can be found. Also, Føtex stores employ various seasonal decorations, soft music and a wider-than-average selection of products[1] to attract patrons.

[1] Approximately 25.000 different products according to the store manager

Seven participants were recruited to take part in this experiment where they were to shop for a predetermined list of items using traditional shopping tools (shopping list, pen and trolley). Following each participant during the test was two researchers, a test-leader asking contextual questions and a data logger recording spatial data. Data collection was accomplished using mp3 recorders attached to both participants and test leader. Through the duration of each test, location information was recorded in the form of coordinates and timestamps by a data logger using a custom position logging application running on a Windows Pocket PC. Each test was would end after a semi-structured interview had been carried out.

The data obtained from this experiment was subsequently analysed with the focus of discerning patterns in the participants‘ use of context and how their attention shifted during the course of the tests. From this analysis the following findings emerged.

*Knowledge of visual appearance and/or physical properties was used to find products*. When a participant knew what to look for it was easier for him/her to find that product. This was especially apparent when a participant did not know what a product looked like since this increased the likelihood of them asking the store personnel for help finding it.

*It was hard to find specific products if many similar ones were present.* All participants had problems finding products that were similar in appearance to nearby products. This was particularly obvious the participants were looking for wine, beer and potato chips since because of a wide selection and hard-to-distinguish packaging.

*Most users would follow a route through the store.* All participants agreed that there was a route through Føtex that would take through all the main areas (clothing, cosmetics, bread, dairy, meats, green groceries and so on). They thought that the route would help them to eventually get near most products and the position data show that they generally tried to follow the route.

*Backtracking for products is annoying.* If a participant passed a product on the list without noticing it on his/her way they felt irritated when having to go back and get it. This phenomenon which more than one participant called ―backtracking‖ happened to all participants in this experiment and they reported it to everything from an annoyance‘ to ‗I‘ would rather leave the store than backtrack‘.

*Shopping list items got check-marked/crossed out.* Every once in a while each participant reviewed his/hers list to mark the items that had already been picked up. More than one participant reported that this was done to make it easier to remember the remaining items they had to get.

*Ask store personnel when a product seems too hard to find.* All participants had to ask for help at least once during their test. This mostly occurred when they were lacking most/all knowledge of a specific product. If a participant knew what a product looked like or which products it could be found among, they were less likely to ask for help compared to when one or both of these factors was unknown.

*Working memory of shopping list.* Instead of looking repeatedly at the shopping list some participants would simply walk down the aisles trusting that they would remember to get products from the list should they stumble upon them by accident. This approach was only moderately successful since these participants would more often than not overlook products if another one caught their attention or if their focus was elsewhere. Similar behaviour was observed when participants would accidently stumble upon a product when in pursuit of another.

*Looking at the shopping list slowed down walking speed.* We observed much lower walking speeds when participants were attending their shopping lists while pushing the trolley. They would usually hold the list with both hands and support their elbows on the handlebar.

*Shopping list order.* All participants said that they would have ordered the shopping list differently according to either product group (bread, dairy etc.) or where the products were located.

*Location signage was rarely used.* There are quite many signs placed in the shopping environment  telling of the products than can be found relative to them. These signs however were rarely noticed and almost never used. It appeared that the signs did not get much attention because of other visual stimuli, decorations and products being the primary ones. A few participants actually confused the decorations with the signs when asked which signs they had noticed.

## Implications

Attention is a factor in all the findings mentioned above. The main issue observed was that the attentive resources of the participants would get stretched to a point where it caused them not to notice relevant products even if these were placed right in front of them. The participants appeared to compensate for the amount of stimuli affecting them by simply by blotting some of them out. This would cause them not to notice signs and also products. If their attention was on finding a specific product and they knew how it looked, they could quite easily oversee products they passed on their way.  Because of the significance these findings have on how attention and attentiveness during shopping it is important to take them into account when designing the context-aware shopping trolley.

The design and implemented prototype based on this research can be found in the articles [13, 14], that can be read from the appendix of this report.

## Contributions

In this section we will present the contents of the two papers that were written as the main contributions from this effort. We recommend that each article is read for the reader to obtain the full knowledge on what our research has contributed to the field of human-computer interaction.

### Research article 1: Drawing Attention to Context-Awareness with CaST: A Context-Aware Shopping Trolley

This first paper examines how a context-aware system can be designed to acquire user attention in a mid-sized Danish supermarket in the Føtex chain. In order to clarify the needs shoppers in this environment may have, an ethnomethodological study [12] was conducted in a Føtex store. For this study we had 7 voluntary participants do a field experiment consisting of them shopping for a predefined list of products using a shopping trolley. While going about their shopping these participants were asked to think aloud in order for us to collect audio data. Each participant was also followed by two researchers, a test leader and a data logger. It was up to the test leader to probe the participant for answers in relation to what their attention was on, which products they were looking for and how they utilised their current context. Analysis of this study yielded the following results.

We found that the Føtex supermarket was a highly complex environment. This complexity arose from the stimuli introduced by thousands of products being displayed, the colourful signs and banners, noise from other shoppers and the in-store music system. Also, Føtex was found to be a very crowded place at certain times in the day. We found that shoppers would overlook products which would later on cause them to backtrack, something that all of them intensely disliked. Backtracking was when a shopper had to walk ‗backwards' on a ‗route' that all shoppers perceived to be present in the store (a U-shaped path spanning the length and width of the retail are). Overlooking products was the result of problematic visual recognition when shoppers either did not know what a product looked like or if they thought it would be located in a different location than the one where they would pass it unnoticed.  Another finding was that the shopping list should in some way be ordered in a way so that similar products was grouped together(i.e. milk, eggs and cheese are one group, fruit and vegetables another and so on.)

Because of the findings mentioned CaST was designed to support the user in the following ways:

when being near a product on the shopping list CaST should demand attention by notifying the user both using visual updates and aural notification through a headset

visual recognition of products should be ensured by presenting the shopper with images

the shopping list presented by CaST should reorder itself accordingly to location and thereby product groups

It was also decided that CaST should present shoppers with their current location and also locations of the items on their shopping list. This was to present the shopper with his/her immediate context in a way that makes it beneficial to pay attention to the system instead of the surroundings.

From an experiment with 18 participants conducted in a Føtex store while it was open, we gathered data from which we evaluated if the design had been successful. CaST was proven to be successful in attracting the users attention through the use of aural notification and continuous updates of the user interface. Because of their high degree of attention on the system, CaST users generally gathered products in a similar order opposed to the seemingly random order in which the products where picked up by the shopping list participants. Furthermore, CaST also travelled a shorter distance and had an easier time finding the products when compared to the shopping list users.

Based on these findings we conclude that the CaST design was successful in acquiring user attention .

## Research article 2: Attention in Mobile Context-Aware Computing: Reducing Context-Complexity By Dividing Attention

This paper presents how an implemented prototype of the CaST design was evaluated in the field. This approach was taken to find out how the attention acquiring nature of CaST could support the shopping activity.

Over the course of one week, eighteen participants took part in an evaluation that was carried out in a Føtex supermarket. We tested in two configurations, one where nine participants used a CaST prototype to shop for a list of predetermined products and another configuration where nine different participants shopped for the same list of items using a written shopping list, a pen and a shopping trolley. Data was collected in the form of audio recordings and location and product collection data logged with a custom made Pocket PC application. Also, the users of CaST were video taped using a camera mounted on the context-aware shopping trolley. During each experiment a test leader asking contextual questions and a data logger using a Pocket PC logging application were also present. Pocket PC was used to gather the position of the participants trolley and to collect a timestamp when a given product was picked up. The same application was used in a Wizard of Oz[2] approach during the tests where CaST was used. After both CaST and shopping list tests a questionnaire and a NASA TLX[3] test was administered.

The data gathered during the 18 tests were analysed and the findings presented in detail. In brief, CaST was found to support shoppers in the following ways:

- Users of CaST travelled a significantly shorter distance compared to shopping list users since they would always find products without having to attend to the complexities of the environment
- CaST users did not have to backtrack to any great extent, in contrast to the users of traditional shopping tools
- The two groups of participants generally spend an equal amount of time picking up products Though individual time spent by CaST users varied significantly it appeared that while using CaST shoppers would spend more time attending to the system before and after having found a product compared to how long shopping list users attended to their shopping lists
- Comparing how hard each group thought it was to find all products it was seen that it was seen that shopping list users had to ask for help finding products a total of 33 times compared to 1 for CaST users
- CaST users generally collected the products in the same order which the shopping list users did not
- In their subjective workload assessment CaST users reported a significantly lower mental workload compared to the shopping list users.

These findings all points toward that the CaST design succeeded in acquiring user attention, and the findings themselves tell how CaST supported the shopping experience. It is based on the results of both research papers that we will now set out to discuss the circumstances under which a context-aware system can reduce task complexity by demanding user attention.

[2] In this approach a ―wizard‖ unknown by the user/participant simulates a functionality such as location awareness, see [16]

[3] The TLX test is designed to provide a measurement of an individual‘s perceived workload.

## Discussion

### Interaction-Mode Comparison

This section focuses on comparing and contrasting the interaction characteristics of the supermarket shopping context and CaST to other documented works on context-awareness.

Given the attention-demanding nature of CaST, and the apparent preoccupation with **reducing** attentional demands alluded to earlier, it may be useful to attempt to categorise and classify the context studied in our research in order to facilitate comparison. Pascoe et al.'s work [15] on Minimal Attention User Interfaces (MAUIs) is interesting in this regard, not only since the MAUI concept appears to represent a polar opposite to CaST's attention acquiring interface concept, but also due to the classification scheme used in the research.

The paper presents a useful tabular format for classifying the interaction characteristics of a use-context. As an example, we show the interaction characteristics of the ecology fieldwork context described in the article below:

| | Visual | Audio | Tactile |
|---|---|---|---|
| Environment (African bush) | | Restricted. Cannot make much noise in case animals are disturbed. | |
| User (ecologist) | | | |
| Task (giraffe observation) | Prohibited. Ecologist will need to keep her eyes on the giraffe under observation. | | |
| Tools (PalmPilot and data collection software) | Small screen (160 × 160 pixel). | No microphone. Very limited audio output through internal speaker. | Four tactile hardware push buttons. Touch screen. |

**Figure 1 - Interaction mode characteristics of the ecology fieldwork activity (from [15])**

This example illustrates the use of the classification scheme. In order to characterize the interaction mode characteristics of an activity, the three modes of interaction (Visual, Audio and Tactile) are represented across the top of the table. In order to describe where in the activity the characteristics originate, the activity is divided into the four aspects environment, user, task and tools. Each of these aspects may prefer, restrict, or prohibit the use of a particular mode. Retrospectively applying this scheme to the supermarket shopping context yields some interesting results.

| | Visual | Audio | Tactile |
|---|---|---|---|
| Environment (Supermarket) | Preferred. The supermarket environment is overly rich with visual stimuli. | Conditionally Preferred. The environment is noisy, so methods to ensure audio penetration should be considered. | |
| User (Shopper) | | | |
| Task (Shopping) | | | Restricted. The shopper‘s task involves collecting products, for which the hands must be free. |

**Figure 2 - Interaction mode characteristics of the supermarket shopping activity**

Comparing the ecology fieldwork activity to the supermarket shopping activity illustrates the contrast in interaction characteristics which intuitively exists between the two. Where aural and visual interaction in the ecology fieldwork context are considered ‗Restricted‘ and ‗Prohibited‘ respectively, in the case of the supermarket shopping context, given the results of CaST‘s evaluation, we claim they are ‗Conditionally Preferred‘ and ‗Preferred‘ respectively.

Perhaps the most unexpected result in supermarket shopping context table is the entry in the ‗Visual‘ column. Given that the visual channel is already overloaded with information, one might expect that the interaction using video would be undesirable. The results of CaST‘s testing, however, suggest otherwise, as CaST users in our evaluation spent a significant amount of time looking at CaST‘s display. Furthermore, CaST‘s users found the completion of the task significantly less demanding than did the users of the traditional shopping list. While we cannot infer causality with certainty here, due to other varying factors involved in the experiments (time spent giving feedback on the system, audio usage) we believe that the diversion of user attention to CaST‘s display was the prime factor in this change. To establish causality, further research is needed.

We believe that this reduction in mental demand is due to the overload of visual information in the store – the results of our field study and testing with traditional shopping tools suggest that shoppers struggle to successfully process the visual information available to them. By drawing user attention to CaST‘s display, the user is given an alternative source for much of the contextual information needed to complete his/her task. We suggest that our findings in this regard might be applicable to other contexts where the human visual resources are taxed; contrary to intuition, adding an attention-demanding, context-aware system to a complex environment from which it is difficult to extract contextually useful information may allow for the reduction of task complexity through division and diversion of attention.

## Conclusion

As described in our research focus, the goal of this project is to provide an answer to the following research question:

> *"Can a context-aware system reduce task complexity by acquiring user attention, and if so, how, and under which circumstances?"*

To provide an answer to this question, we answer our other two questions first.

> *"How can we design a context-aware shopping trolley to acquire user attention?"*

This question is addressed through our first research paper. By researching the supermarket shopping context in a field study, an understanding of the nature of the context and the issues it presents are developed. This understanding forms the basis of a system design that provides the shopper with contextually useful information in a timely manner. This design was implemented in the form of a context-aware shopping trolley called CaST.

CaST supports the shopper's understanding of his/her context in a number of ways through 4 of the elements of context (Task, Location, Objects, People). In order to acquire user attention the CaST utilizes aural notification, channeled through a Bluetooth headset to ensure penetration.

Evaluation of CaST indicates that the design and aural notifications were effective in acquiring user attention, evidenced by marked differences across numerous parameters, including distance moved, product collection order and mental demand (provided by NASA TLX). In addition to acquiring user attention, CaST was able to maintain possession of that attention to an unexpected level, likely due to the dynamic and continuously updating nature of its graphical user interface.

Having designed a system that acquires (and maintains) user attention, it is necessary to investigate the manner in which such a system supports the shopper.

> *"How can an attention-acquiring, context-aware shopping trolley support the shopping activity?"*

This question is addressed through our second research paper. CaST was evaluated in the field as part of a comparative study where 18 shoppers were set in a shopping scenario with either CaST or traditional shopping tools. Each session involved the shopper, a test leader and a logger. The shopper carried out the shopping task while the test leader elicited feedback from the shopper and the logger recorded movement and product collection data.

The results of the evaluation show that, compared to the users of the traditional shopping tools, CaST users walked a significantly shorter distance with their trolleys, did not have to backtrack, found shopping significantly easier, and bore a significantly reduced mental workload (according to NASA TLX). Shoppers from both groups spent a similar amount of time completing the shopping task on average.

Having ascertained that CaST, an attention-acquiring context-aware system, supports the shopper in numerous ways, we turn to the discussion of our results to answer our first research question.

> *"Can a context-aware system reduce task complexity by acquiring user attention, and if so, how, and under which circumstances?"*

CaST's evaluation results indicate that the complexity of the shopping task was reduced. The significant difference in mental demand indicated by the NASA TLX results, and the disproportionate need for help of the shoppers using the traditional shopping tools are strong indicators of this.

CaST achieves this effect by providing an alternative source for contextually useful information (such as notifications of nearby products, locations of products in relation to the shopper and images of products) to shoppers, and ensuring they are aware of this information. Shoppers appear to struggle to successfully process the visual information available in the environment to accomplish their task, and CaST's users spent a significant amount of time looking at CaST's display. Given the reduced mental load and need for help exhibited by CaST's users in the evaluation, we find that CaST's presentation of contextual information was easier to process and understand than using the environment. As such, by diverting attention away from the complex environment, and providing a more easily tractable source for useful information, CaST reduces the complexity of completing the shopping task.

By defining the interaction mode characteristics of the supermarket shopping activity, we are able to highlight the traits of the use-context which we believe are key to the success of the attention-acquiring approach employed by CaST. By identifying the overloaded visual channel present in Føtex, and providing an alternate source of visual context information, CaST reduces task complexity. We suggest that complex environments from which it is difficult to extract contextually useful data are potentially well suited to the introduction of an attention-acquiring context-aware system.

## Limitations

Our aim for this project was to contribute knowledge on how task complexity could be reduced by context-aware systems acquirering attention. Based on the results we have presented in this report and the two research papers it is clear that four the shopping case in Føtex, task complexity was reduced by CaST. This result however, is not generalisable since CaST is designed especially for shopping in a particular Føtex branch. Since other environments will differ in context the results from CaST cannot be recreated elsewhere.

## Further work

The successful evaluation of CaST opens a number of interesting research possibilities. While the attention acquiring behaviour of CaST proved effective, there is little research to compare the system and results to in order to ascertain whether it is the most effective approach to a context-aware shopping aid. While we believe this to be the case, it would be necessary to evaluate systems using other approaches in order to confirm or disprove this belief. As an example, it could be interesting to deploy a minimal attention user interface system similar to one of those described in [15] to see how such a system would affect the shopping activity and compare it to our findings.

As alluded to in our articles, CaST‘s attention acquisition mechanism functioned extremely well, but the manner in which CaST maintained user attention came as a surprise. We had envisioned that CaST allow for passive usage whereby shoppers would follow the route around the store, browsing products of interest, free of the burden of actively looking for the items on their list. When they reach a position where a product could be collected, they would be notified. In retrospect, the dynamic and continuous updates of the map are likely to attract attention, as are some of the other graphical features of CaST‘s user interface. Nonetheless, we believe that there is a possibility that there was a novelty factor at play in this attentional effect. Furthermore, it is quite possible that the nature of system usage would change once shoppers grew accustomed to using CaST and understood its functionality better. We suggest, therefore, that in order to fully understand the use of CaST a much larger study be conducted.

In addition, while a Bluetooth headset was used in the CaST prototype to ensure users were aware of CaST‘s notifications, this is an unlikely solution for a production system failing a drastic change in the social practice of wearing such devices. Our initial design ideas for CaST included an alternate proposal for this mechanism – the use of tactile feedback through the trolley‘s handlebar. We believe that the restriction noted on tactile interaction in our discussion would not effect such a system since notifications only occur when the trolley is moving, and when the trolley is moving the shopper‘s hands are likely to be on the handlebar.

The research direction which is likely the most critical for the commercial success of systems like CaST, however, concerns promotional material. During evaluation, questions were been raised as to the extent to which a retailer such as Føtex would benefit from the use of a system like CaST. As noted, CaST was extremely effective in acquiring user attention and as a result, awareness of the physical environment in Føtex (advertisements, promotions, signs, products) was drastically decreased. Clearly, to be of interest to the store, the system should support some kind of promotional function – as Føtex‘s manager told us numerous times, impulse purchases constitute a large percentage of Føtex‘s revenue. The manner in which such a promotional function should act and present is unclear. Furthermore, the CaST concept allows for new and novel forms of promotion – giving CaST data-mining capabilities could allow for analysis of shopper behaviour and purchasing habits on a level previously unexplored. Such functionality could aid in preventing promotional functions being viewed in the same way as the much-maligned ‗pop-up‘ common to the World Wide Web. The real challenge though in this regard lies in once again finding a usable technique to acquire user attention without negatively affecting their interaction with the system or their shopping experience. The crux is in striking a balance, since failure to draw attention to promotional material could result in falling profits for the retailer, while introducing undesirable complexity to the system could negate benefits to the shopper and cause usage to dwindle.

All promising, fledgling technologies require a great deal of research before they can be fully understood and their potential harnessed. We hope that this thesis illustrates some of the promise that systems like CaST hold, so that the required research is undertaken.

## References


1. Alm, H., Nilsson, L. The Effects of a Mobile Telephone Task on Driver Behaviour in a Car Following Situation. Accident Analysis and Prevention 27(5), Elsevir Science Ltd. (1995) 707-715

2. Green, P. Crashes Induced by Driver Information Systems and What Can Be Done to Reduce Them. Proceedings of Convergence 2000 Conference.

3. Dourish, P. What We Talk About When We Talk About Context. Personal and Ubiquitous Computing 8(1), Springer London (2004), 19-30
4. Chalmers, M. A Historical View of Context. Computer Supported Cooperative Work (CSCW) 13(3-4), Springer Netherlands (2004), 223-247

5. Schilit B. N., Theimer M. M. Disseminating Active Map Information to Mobile Hosts. IEEE Network 8(5), IEEE (1994), 22-32

6. Cheverst, K., Davies, N., Mitchell, K., Friday, A., Efstratiou C. Developing a Context-aware Electronic Tourist Guide: Some Issues and Experiences. *Proc. CHI 2000*, ACM Press (2000), 17-24.

7. Lonsdale, P., Beale, R., Byrne W. Using Context Awareness To Enhance Visitor Engagement In A Gallery Space. *Proc. HCI 2005*

8. Skov, M. B, Høegh, R. T. Supporting Information Access In A Hospital Ward By A Context-Aware Mobile Electronic Patient Record. Personal and Ubiquitous Computing 10(4), Springer London (2004), 205-214

9. Bohnenberger, T., Jameson, A., Krüger, A., Butz, A. Location-Aware Shopping Assistance: Evaluation of a Decision-Theoretic Approach. *Proc. Mobile HCI 2002*. Springer Berlin (2002), 18-20

10. Dey, A.K., Barkhuus, L. Is Context-Aware Computing Taking Control away from the User? Three Levels of Interactivity Examined. *UbiComp 2003*, Springer-Verlag (2003), 149–156

11. Aylott, R., Mitchell, V.W. An exploratory study of grocery shopping stressors. International Journal of Retail & Distribution Management (1998), 362-373

12. Oulasvirta, A., Tamminen, S., Roto, V., Kuorelahti, J. Interaction in 4-Second Bursts: The Fragmented Nature of Attentional Resources in Mobile HCI. *Proc. CHI 2005*, ACM Press (2005), 919-928
13. Black, D.J., Clemmensen, N.J. Drawing Attention to Context-Awareness with CaST: A Context-Aware Shopping Trolley. *Master Thesis in Computer Science,* Aalborg Universitetsbibliotek (2006)

14. Clemmensen, N.J., Black, D.J. Reducing Task Complexity by Dividing Attention: Exploring a Context-Aware Shopping Trolley. *Master Thesis in Computer Science,* Aalborg Universitetsbibliotek (2006)

15. Pascoe. J., Ryan, N., Morse, D. Using While Moving: HCI Issues in Fieldwork Environments. *TOCHI 2000*, ACM Press (2000), 417-437

16. Dearman, D., Hawkey, K., Inkpen, K. Effect of location-awareness on rendezvous behaviour. *Ext. Abstracts CHI 2005*, ACM Press (2005), 1929-1932.

## Appendix 1

Black, D.J., Clemmensen, N.J. Drawing Attention to Context-Awareness with CaST: A Context-Aware Shopping Trolley. *Unpublished*

# Drawing Attention to Context-Awareness with CaST: A Context-Aware Shopping Trolley

**Darren Black**
Department of Computer Science
Aalborg University
Frederik Bajers Vej 7E
DK9220 Aalborg, Denmark
drdaz@cs.aau.dk

**Nils Jakob Clemmensen**
Department of Computer Science
Aalborg University
Frederik Bajers Vej 7E
DK9220 Aalborg, Denmark
njay@cs.aau.dk

**ABSTRACT**

This paper describes the design of a mobile context-aware shopping system called CaST (Context-Aware Shopping Trolley). The system is designed to support shopping activity in a supermarket setting through context-awareness and acquiring user attention. The system"s design is based on an understanding of supermarket shopping needs and behaviour derived from our previous research in the field, together with approaches informed by our previous theoretical research. The prototype discussed and described in this paper is developed to cater to the needs of shoppers who frequent the East Aalborg branch of Føtex, a medium-sized Danish supermarket chain. Results from the evaluation of CaST show that it succeeded in acquiring (and maintaining possession of) user attention.

**Author Keywords**

Supermarket, shopping, context, context-awareness, attention, location-awareness, audio, notification, design, CaST.

## INTRODUCTION

Use of the term "context-awareness" in the HCI literature has grown enormously over the past decade. Students and researchers have been scrambling to apply the concepts to, and harness the apparent potential in, numerous domains. To this date, despite the promise held by the concept of context-aware computing, there is little evidence that the research conducted has spawned commercially successful applications. Furthermore, while context-aware computing has been sometimes viewed and presented almost as a panacea, the implementation of context-aware applications and their subsequent testing has revealed numerous challenges to its successful use.

With respect to our chosen domain, the supermarket, recent times have seen trials of numerous different types of new in-store technology. Concept stores such as Metro Groups Future Store [1] have started using radio-frequency identification (RFID) tags to streamline the supply chain and as part of a checkout-free store concept. Furthermore, after beginning our research, we discovered that electronic shopping aid products have been launched by at least two IT companies (IBM and Fujitsu) and deployed in a select few supermarkets across the globe. Both of these systems appear to employ elements of what the HCI literature refers to as context-awareness. Documentation of these systems is sparse and generally promotional in nature however, and as such the manner in which such systems affect the shopper warrants research. As part of this research, CaST was devised and implemented as a prototypical context-aware shopping aid.

In addition, we have a belief that under certain conditions, context-aware systems may benefit from being designed to acquire user attention. As such, this paper focuses on the following question:

*"How can a context-aware shopping trolley be designed to acquire user attention?"*

## RELATED WORK

There are several examples in the literature of attempts to implement computerised aids for the supermarket shopping domain.

### Context-aware mobile systems

Context-aware computer applications can, broadly speaking, be characterised by their ability to discover and react to changes in the environment [2]. Here, the word environment is used synonymously with context, as the application is described as aware of its environment and reacting to changes in said environment.

The purpose of context-aware applications in general is to provide task-relevant information and services to the user. The systems are designed to achieve this goal by autonomously updating in reaction to changes in their context. It is relevant, therefore, to include an understanding of the user‟s task when implementing a context-aware system.

The notion of context, then, is important in the definition of context-awareness. Researchers have defined context in numerous ways, and as involving numerous (usually inter-related) elements. These elements include, but are not limited to:

Location [3]

Objects [3]

People (Social context) [3, 4]

Task

With advances in mobile technology, location awareness has become more interesting and viable for research in the past decade. Quite simply, where stationary computers (and their users) are located in a fixed location, mobility introduces the potential for change in location. With changes in location, user needs can change, and location-aware systems are designed to react accordingly to changes in location [5].

There are numerous examples of context-aware systems in the literature, the vast majority of which exhibit location-awareness. Mobile tourist guides are typical examples of context-aware systems with perhaps the most notable example being the Lancaster GUIDE project [6]. Other examples of context-aware systems include electronic patient records [7], more general hospital applications [8], museum guides [9] and university guides [10].

With regard to objects and people, [3] defines context as "any information that can be used to characterize the situation of entities (i.e. a person, place, or object) that are considered relevant to the interaction between a user and the application themselves". We say therefore that any objects or people that are of relevance when using a system are a part of the user‟s, and system‟s context.

### *Context-awareness and attention*

We have noticed a recurring issue that shows in testing context-aware applications; namely that updates which occur while user attention is away from the system can be unexpected and produce undesirable results. For example, in [7], while testing the context-aware patient record, users looked at the system while in one room in the hospital, stopped looking at the system while moving to another room, and looked at the system again in that room. For some subjects this caused confusion, while for others, more serious problems occurred.

In a similar manner, [11], in testing of a shopping mall guide system, reported that the need to constantly attend to the system while navigating the mall was considered a drawback.

As noted in [12], the notion of ubiquitous and context-aware computing has at its heart a notion of the system fading – "the systems we design should be [… ] objectively visible but subjectively invisible" [12]. We suspect this invisibility lies at the root of the issues described above, and have found no examples of context-aware systems which actively demand user attention in the literature. As such, we find reason to focus our research on how to design a context-aware mobile system that demands user attention, and the effects of such a system in its use-context.

### *Context-awareness and shopping*

There are few documented examples of the implementation (and effects thereof) of context-aware mobile systems in the shopping domain. Interest in applying context-awareness to the supermarket-shopping domain can be clearly seen, however, in the concepts of the Future Store Initiative[1]. The various presentations and rendered scenarios depict, amongst other things, context-aware shopping trolleys and ambient displays.

[11] documents the implementation and testing of a decision-theoretic shopping mall guide. The system works on a „macro‟ level, instructing the user which shops to visit, and in which order, to make their shopping activity more effective. The system achieved this goal using an extremely simple interface, which directed the shopper towards shops using arrows. The system proved both effective and likable according to testing, reducing time spent shopping by a small but significant amount (11%). Issues highlighted included users feeling they lacked an overview and felt like they were being "led blindfolded" through the mall.

## CASE: FØTEX – A MEDIUM-SIZED SUPERMARKET

We chose to base our research at the eastern Aalborg branch of Føtex (a chain of medium-sized supermarkets). This site was chosen for its geographic properties – it is situated extremely close to the university campus. The following describes our field study.

### Field Study – Exploring use of context

We undertook an ethnomethodologically [13] inspired study of the ways in which context is used by shoppers while, and in order to, undertake the shopping activity.

The study consisted of a number of shopping sessions, each involving a single shopper, a test leader and a logger. The test leader conducted in-situ contextual questioning on the shopper. The logger recorded the shopper‟s movement around the store on a specially developed PDA application.

A total of seven shoppers were brought to the Føtex store and monitored, questioned and observed while shopping. Five of the seven shoppers were provided with a randomised, 29 item, shopping list to shop by, while the other two had shopping trips scheduled and thus brought

[1] http://www.future-store.org/


**Figure 1 - The east Aalborg branch of Føtex**

their own lists. The lists provided contained a blend of everyday groceries and less frequently purchased items to ensure that the participants would need to cover most areas of the shop floor. Their movement through the store was logged, and an audio recording was made of their utterances. Both the logger and the test leader wore audio recording devices to facilitate recording observations.

Following the shopping sessions semi-structured interviews were conducted to obtain further contextual and demographic data for analysis.

In total approximately 21 hours (3 audio tracks, 7 hours each) of audio data were collected, along with movement data for each session. The audio tracks for each session were synchronised with each other and the movement data to facilitate analysis of the spoken data in its spatial context.

### Findings

The data were analysed in order to generate an understanding of the shopping process and understand how and why it can be supported by a context-aware mobile system. These findings would form the basis of the design of CaST, and represent a set of challenges to overcome for successful implementation. In the following we elaborate on each of these challenges in turn.

*Highly Complex/Crowded Environment*

Føtex, like many other supermarkets, presents shoppers with an onslaught of stimuli. Countless, brightly coloured signs hang down from the ceiling informing of products and offers. Music, audio adverts, and announcements play over the PA system. Aromas from various products fill areas of the shop floor. Shelves are crowded with brightly coloured products and packages. All of these sources compete for the shopper‟s attention while in store. We believe that this complexity contributes to the shoppers‟ difficulties in locating items both in and of itself, and manifesting in the other challenges faced (see below).

*Shopping with a trolley is a multitasking activity*

Supermarket shopping with a trolley is in its essence an activity that requires the shopper to multitask; in addition to studying the displays and products in the store in trying to find needed goods, the shopper must also maintain awareness of the positions of nearby people and objects in order to manoeuvre the trolley and avoid collisions. All of these tasks require visual focus, and the shoppers‟ visual resources are insufficient to cope with all of them simultaneously. This factor is likely to play a significant role in shoppers overlooking products (see below).

*Shoppers overlook products*

The participants had a tendency to not notice products despite sometimes extremely close proximity. This phenomenon was caused by a myriad of conditions, sometimes due to product recognition (or lack thereof) and sometimes due to a belief that the product in question was located elsewhere. On other occasions, participants passed by needed products since they were looking for another item and were focused on that task.

*Backtracking causes frustration*

The physical layout of Føtex encourages shoppers to follow a U-shaped route through the store. While this is unsurprising, the extent to which this route holds psychological and social weight was unexpected. Participants elucidated disdain for any need to „go back‟ on this route – two went as far as suggesting that they would rather leave the store without purchasing a product if picking it up meant that they had to backtrack a significant distance.

*Shopping list order should reflect product groupings*

All participants said that a shopping list would always be ordered in some fashion. Participants were offered the opportunity to re-order the list they were provided, but only one did so. Opinions as to how such a list should be ordered varied – some claimed that it would be by where they thought things were placed in the shop, while others would use a mental model of product groupings to order the list (the grouping of milk, cheese and eggs was common, for example).

*Visual recognition of products can be problematic*

The importance of visual recognition of products in the shopping process was exposed during the course of the study. Simply put, if the shopper didn‟t know what the packaging of a product looked like, it was hard for them to find it. While seemingly obvious, this factor can come into play in numerous situations – when a product‟s packaging changes or when looking for an alternative to the product/brand usually taken, for example. There were instances in the study where the condition of the participant knowing the appearance of the product failed. In these instances the participant exhibited a great deal of difficulty and frustration.

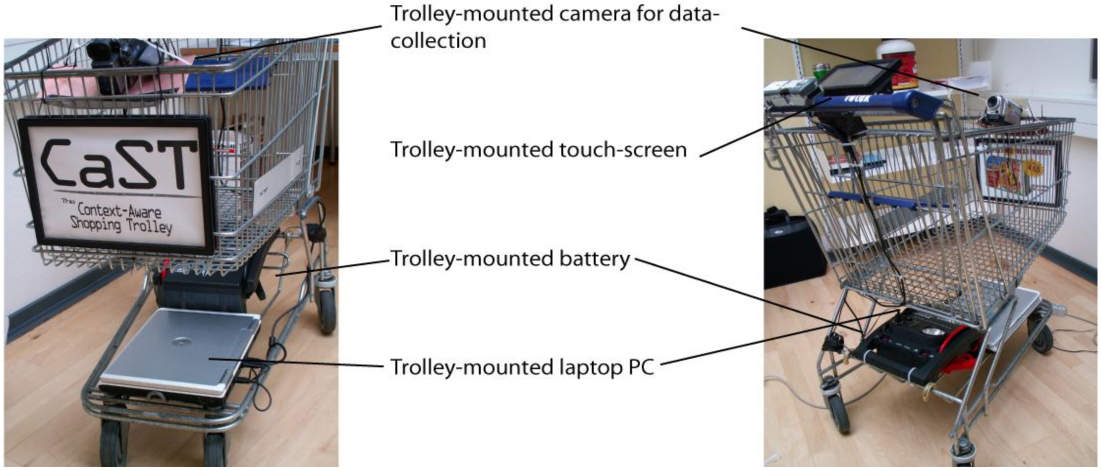


**Figure 2 – Physical appearance of the CaST prototype.**

## CAST – THE CONTEXT-AWARE SHOPPING TROLLEY

In the following section we describe the considerations, design process and resultant design that form the experimental CaST prototype.

### Approach – Context-awareness applied to supermarket shopping

The challenges faced by shoppers, described above, can be supported by the use of a context-aware mobile system. Each of the challenges described are rooted in one or more of the elements of context described earlier. As such the application of an active context-aware system [14] to this domain can support shoppers by providing information which is updated autonomously as their context changes.

Operationalising the definition of context given earlier, we define the context of shopping in Føtex as follows:

Task – to collect the items on the shopping list

Location – the location of the shopper, as well as the locations of products and shelves and the spatial relations between all three.

Objects – the physical properties and states of products and shelves.

People – the other shoppers. We see social context as manifesting in shoppers" need to follow the route through the store. Since the vast majority of shoppers are walking in one direction backtracking is troublesome, much like driving on the wrong side of the road. In addition to physical issues, the route appears to be considered a social norm.

#### *Managing User Attention*

Returning to the „invisible" nature of context-aware systems, we suspect that it is this invisibility that lies at the root of some of the issues highlighted in documented tests. In order to test this theory, CaST was designed with features intended to acquire the user"s attention.

As noted, supermarket shopping with a trolley is a multitasking activity that requires visual focus on numerous entities for safe and successful execution. As such, we cannot expect that the user will always have their attention on CaST"s graphical user interface, and thus cannot rely on visual updates being noticed. Again, similar conditions are apparent in several documented context-aware systems and have caused various problems.

To ensure that the user is aware of CaST"s notifications, a different modality was used – aural notification is used to obtain the user"s attention. The supermarket is a noisy environment and as such small speakers are unreliable as devices for user notification. To ensure that CaST"s notifications are heard, shoppers are provided with a Bluetooth headset through which all system audio is channelled.

### Design Process

The task of designing CaST was a gradual and iterative process. The first three weeks consisted of brainstorming sessions where approaches and concepts were developed, discussed at length, and for the most part, discarded. Defining the form of interaction that the system would offer proved especially taxing. The final design reflects what we consider to be a strong (but by no means authoritative) proposal for the design of a context-aware shopping aid.

### Physical Design

Our solution involves the use of a trolley-mounted, touch-sensitive TFT screen (see Figure 4). Self-contained devices are available in this format and could be used in a production version of CaST; however the unit used for this prototype is only a touch-sensitive screen – the application runs on a trolley-mounted laptop PC. This touch-screen is powered by a trolley-mounted battery (see Figure 2).

### Architecture

All the components of CaST were built on Microsoft"s .NET 2.0 framework using C#. The recently released Visual Studio 2005 was chosen as a development environment due

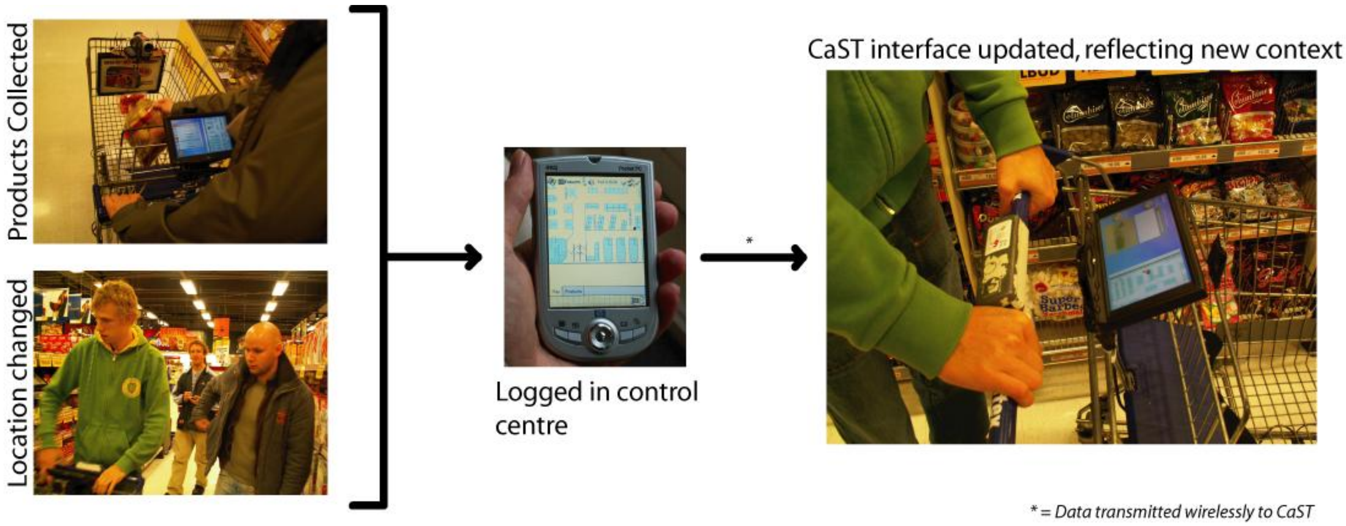


**Figure 3 - Illustration of control centre functionality. User activity is logged in the control centre and the new data sent to CaST. CaST updates to reflect the altered context.**

to good experiences with its predecessor, Visual Studio .NET 2003. We feel that this was generally a good choice of development environment for the purpose, although we encountered some issues with the inheritance behaviour of some of Microsoft‟s included visual objects. In effect, inheriting from a subset of the visual classes included in Visual Studio causes the Designer component of the environment to malfunction in various ways. As such it was necessary to seek similar classes from third party sources. In addition, CaST‟s data was stored in a Microsoft Access database to allow for fast and simple entry and alteration.

In total, the prototype of CaST amounts to (approximately) 3000 lines of C# code, a 300 entry Access database, and 45MB of assorted graphics used for icons, maps and backgrounds.

*Sensing Context / Control Centre*

While the implementation of CaST for production would require the use of both positioning sensors and RFID sensors to register product collection, development and implementation of these technologies lies outside the scope of this project. In order to test the system it was therefore necessary to devise a system that would allow us to take the place of these sensor devices.

For this purpose a control centre application was implemented on the .NET Compact Framework 2.0 and deployed on a Pocket PC device. The application consists of two tabbed windows – one containing a map of Føtex allowing for the updating of the shopper‟s location in CaST, and the other containing the list of products in the system such that the system can be updated when items are collected. In addition the control centre program logs location data and product collection events while maintaining their temporal context, allowing for later analysis.

The application uses a standard TCP/IP connection to communicate with CaST (a server side was added to CaST for this purpose), allowing for simplicity in switching between networking technologies. In our testing, Bluetooth was used and proved both stable and responsive.

**Interface Design**

CaST‟s graphical user interface presents the information essential to the shopping activity at contextually appropriate times. The system supports and supplements the user‟s awareness and understanding of several elements of the shopping context.

The 16:9 screen format is divided into two sections; in its basic state the left side of the screen shows the user‟s shopping list, while the right side shows a map of Føtex (see Figure 8).

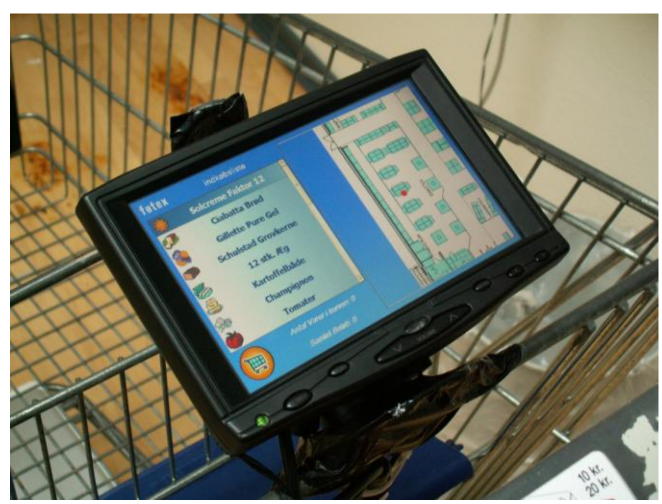

**Figure 4 - Trolley-mounted touch-screen**

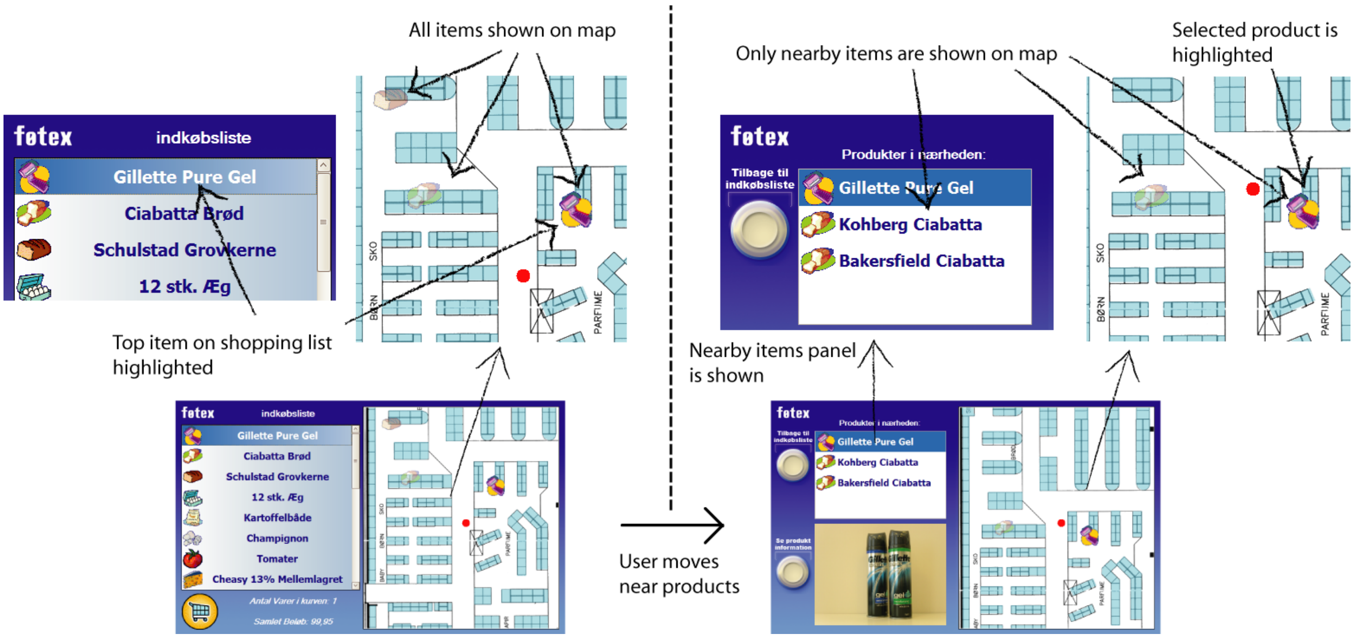


**Figure 5 – [Left] CaST's GUI in its base state. [Right] CaST's GUI when products (Gillette Pure Gel and Ciabatta Bread) are nearby.**

CaST supports shoppers by sensing the user"s context and, where necessary, acquiring the user"s attention. In the following, we describe the manner in which the elements of the user"s context are utilised and supported.

*Task*

The user"s task when shopping with a list is to collect the items on that list. The inclusion of the shopping list component in CaST gives a direct representation of that task. The dynamic ordering of the list presents the sub-parts of that task in the order which best suits the shopper"s current context.

The shopping list provides a reference point for the shopper where he/she can see what needs to be done before their task is considered complete. In order to support the user in this way, the list updates when an item from the list is collected and put into the trolley. The system also shows the total value of the items in the trolley – for production this functionality should likely be extended to allow the user to review the items in the trolley, as well as remove items from the trolley however the version tested does not allow for such activity.

*Location*

Location is included in CaST"s design in the form of the locations of the shopper, products and shelves, as well as the spatial relations between all three. CaST provides location information in several dimensions. In addition to showing and reacting to the spatial relations between products and the trolley, the system also represents spatial relations between:

Trolley – Shelves

Products – Shelves

Products – Products

Through the use of the map the system offers the user a resource with which they can orient themselves. The map shows a top-down view of Føtex, and thus depicts the layout of the shelves and aisles. The items on the user"s shopping list are represented with icons corresponding to those displayed in the shopping list to aid recognition. Finally, the map represents the user"s position as a red spot.

As the shopper moves with CaST the map updates; the red spot stays in the middle of the map"s display area and the map moves such that the red spot correctly depicts the shopper"s location. Furthermore, the shopping list reorders itself according to the proximity of products.

In addition to supporting the user"s awareness of his/her location, the system uses its awareness of its location and the location of products to inform the user of nearby products which are on his/her shopping list. When the user nears a product (or products) the system sends an audio alert through the user"s headset and displays a list of nearby products. This list is displayed in a panel that pops up from the bottom of the screen, covering the shopping list (see Figure 5). The location of an item on the list can be shown by tapping that item – its icon is then highlighted on the map. In this state, only products that are considered nearby (i.e. listed in the popup) are shown on the map; all other icons are temporarily removed to reduce complexity.

To achieve this functionality, each product was associated with a rectangular area of the shop floor where the product is considered nearby. These areas were defined such that the shopper would be informed of his nearness where it would be feasible to collect the product in question (see Figure 6).

All of these representations are offered to support the user‟s understanding of their context such that they may locate products more easily.

*Objects*

Objects in the shopper‟s context in Føtex are included in CaST in the form of the physical properties and states of products and shelves. CaST supports the shopper‟s awareness of objects in his/her context in multiple ways:

- Location of objects
- Visual appearance of objects
- Existence of + relations between objects
- Descriptive information about objects

CaST‟s core functionality combines the first two dimensions by providing a photograph of products that are nearby. This photograph is included on the panel which appears when products are nearby, and is updated if/when the user selects a different nearby item from the list.

CaST supports the shopper‟s knowledge of the **existence of and relations between objects** by showing similar and related products to those on the shopping list. The user can select an item from the shopping list to view a list of alternative products. In a similar manner to the panel displaying nearby products, a panel appears which covers the shopping list when an item is selected (see Figure 7). From this panel, the user can select an alternative product, displaying its picture, and view more detailed information related to the product.

This functionality has been included for multiple purposes – it facilitates more traditional „information pull‟ interaction with CaST and thus allows the system to be useful in cases where its own recommendations are deemed otherwise. Additionally, in a production version of the system, this panel would allow the user to choose one of the alternative products and replace an item on his/her list with it. This

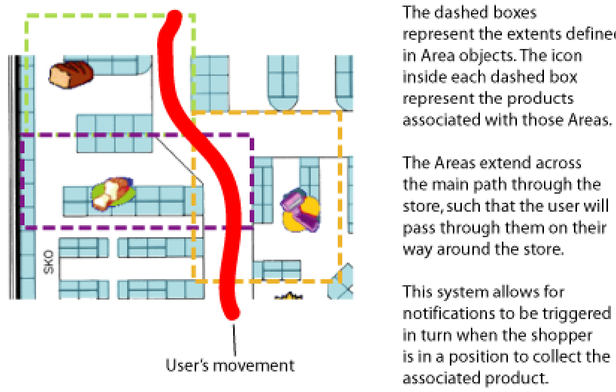


**Figure 6 - Illustration of area system underlying CaST's location-based notification mechanism**

option, while planned, did not make it into the tested version.

CaST provides **descriptive information about objects** by allowing the user to view information about any product, along with a larger picture of the product. This information is displayed in a panel that pops up from the bottom of the screen, and covers the map (see Figure 9). This panel can be called from either the nearby products popup, or the alternative products popup. The information shown in the version tested is minimal, but could easily be expanded to suit most requirements.

We note that there are some abstraction challenges inherent to designing a shopping aid system like CaST with regard to products ([11] reported similar issues). CaST implements two levels of product generalisation – specific products (e.g. Gillette Pure Gel) and product groups (e.g. Shaving Gel). In the event that a product group is entered in the shopping list, all the products in that group are displayed when they are nearby. For instance where "Bacon" is an item on the shopping list, and the shopper is near the bacon products, he/she is shown the various types of bacon on offer (see Figure 8). Conversely where a specific product is on the shopping list, only that product is shown.

By offering the map of Føtex containing the physical layout of the store, the user is provided with contextual


**Figure 8 - Nearby products when "Bacon" is a shopping list item, and the product is nearby**

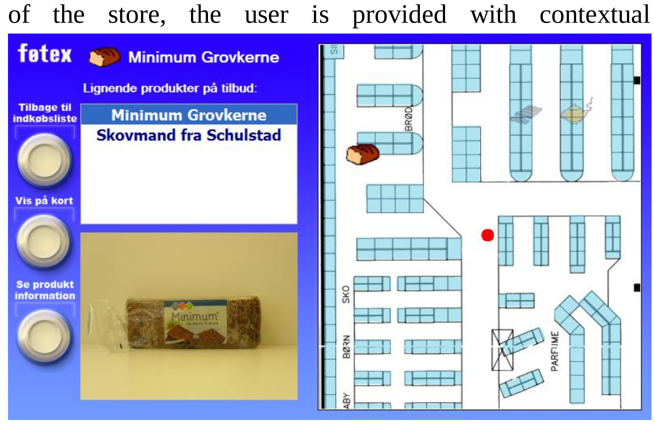


**Figure 7 - Alternative products list**

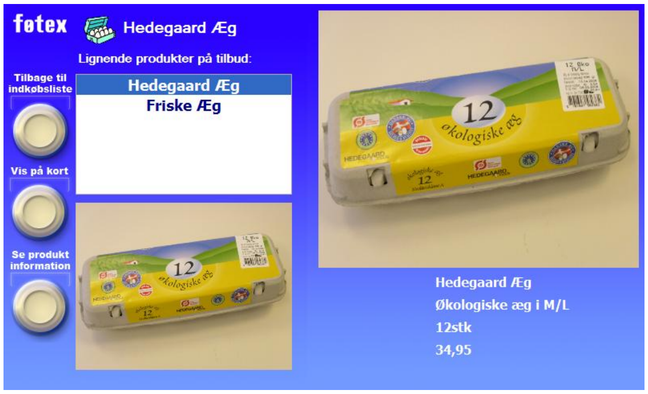


**Figure 9 - Product information panel**

information related to the objects in the physical environment that would otherwise be unavailable.

*People (Social Context)*

CaST‟s design incorporates support of the supermarket‟s social context through its dynamically ordered shopping list. As previously described, the shopping list component continues to display items which haven‟t been collected, but which have been „passed‟ by the shopper, as the top item on the list. The system does so despite other products being physically closer to the shopper. In doing so, the system encourages the user to collect the „missed‟ item before proceeding with the rest of their shopping and gives the user the opportunity to avoid backtracking.

In order to achieve this functionality, the store was divided


**Figure 10 - Division of shop floor into blocks**

into four blocks, derived from the movement data obtained in our field study. All products located within a block are associated with that block. The blocks are numbered sequentially, as can be seen in Figure 10. CaST provides location-based updates to the shopping list and location-based notifications as long as the shopper collects the products in their current block before moving on to the next block in the sequence.

## EVALUATION

In the following we describe the purpose, method and results of our evaluation. Evaluation of the system was carried out in the field; in-store at Føtex.

### Purpose

The purpose of our evaluation is twofold, in line with the dual research foci given at the start of this paper. Answering the first question posed requires data that illustrates differences between shopping with traditional shopping tools, and shopping with CaST. Answering the second question requires data that illustrate the extent to which CaST successfully acquires user attention when in use.

### Method

In order to obtain data that could help answer our first research question, each evaluation session took one of two configurations to allow for comparative analysis of data; half of the sessions were conducted to study shopping activity using CaST, while the other half were conducted to study the shopping activity using a traditional trolley and paper shopping list. The data relating to our second research question would be extracted from the group of CaST users.

A total of eighteen subjects took part, aged between 24 and 56. The group of shoppers who used CaST had an average age of 35 (M=35.11, SD=13.79), and 3 of these subjects shopped at the east Aalborg branch of Føtex at least once per month. Those using the traditional shopping tools had an average age of 27 (M=27.44, SD=3.57), with 4 monthly (or more frequent) shoppers at the Føtex in question.

In a similar manner to the field study described earlier, a 23 item shopping list was created, containing a blend of items which are considered daily goods, as well as items which are less frequently purchased. All participants were informed to envision a scenario where they had been sent shopping for all the members of their household. As such, many items on the shopping list would be easily recognisable, while others would not.

The group using traditional shopping tools were presented with a shopping trolley, the randomised, 23 items shopping list and a pen and offered a short time to examine and/or rearrange the list if needed. The system users were presented with CaST and given a brief introduction to the functionality of the system. Both groups would then proceed with their shopping task. In a similar configuration to the field study, a test leader to elicit feedback, and a logger to record movement and product collection data accompanied the shoppers. Each participant was equipped with an mp3 player to capture audio data from the shopping session.

Following the shopping session the participants were taken to the store‟s cafeteria, where they were asked to complete a questionnaire that included NASA‟s TLX test and questions to obtain demographic and other information related to the shopping session.

### Results

#### *Distance travelled*

Participants using the traditional shopping moved their trolley an average of 107.4 metres further than those using CaST. This represents an average distance increase of 31.8%. This difference is statistically significant ($t(16)=-4.087$, $p<0.001$). The shoppers using traditional tools backtracked noticeably more than those using CaST. The only CaST users who backtracked were those who opted to collect items in a different order to that recommended; these shoppers said they were aware of CaST‟s recommendations but felt there were closer items and opted to collect those instead.

#### *Performance*

In spite of the sizable difference between the groups in distance travelled, there was no significant difference in the time taken for each group to collect all the items on the list.

Our data indicates that the CaST users found it significantly easier to find products easier than the group using traditional tools. This finding is supported data showing shoppers using the trolley and paper list asked for assistance 33 times, while only once did a CaST user need help finding a product[2]. Similarly the results of NASA TLX show a significant ($t(16)=-2.292$, $p=0.036$) reduction in mental demand for users of CaST (43.44) compared to users of the traditional shopping tools (63.89). The combined, weighted TLX score difference, while not statistically significant ($t(16)=-1.842$, $p=0.084$), suggests a tendency towards lighter workload when shopping using CaST (TLX=31.37) compared to shopping with a trolley and paper shopping list (TLX=44.04). Clearly, the system‟s contextual information was noticed, understood, and used by the CaST group, resulting in these marked differences.

#### *Product Collection Order*

The order in which the CaST users collected products was notably more uniform than the users of the traditional shopping tools. The CaST users picked up the same product at the same point in the product collection sequence 131 of 207 times, compared to 79 of 207 times for the trolley and paper list users. This result is highly significant according to Fisher‟s exact test.

These data represent arguably the most significant indication in our findings that CaST successfully acquired its users‟ attention during the tests. We view this as evidence that CaST‟s notifications and updates were noticed, and its recommendations followed.

#### *Observations*

Shoppers using CaST showed a tendency to devote an increasing amount of attention to the system as the session progressed. Initially the CaST users entered the shop floor and only glanced occasionally at the display. Following the first audio notification, and subsequent product collection, most users gradually reduced their sampling of the physical context until some became almost totally reliant on the system for guidance. Several CaST users reached points where, after blindly trying to move the red spot towards the icon on the map, they exhibited a moment of clarity, exemplified by the following remark:

*"Hey, I know where the eggs are, they're just over there! I'd completely stopped using my intuition."*

Instances such as this indicate that not only did CaST acquire the shoppers‟ attention at the key times intended by its design; it maintained possession of their attention to an unexpected degree.

Also of note is what can be interpreted as attention division techniques on the part of the CaST users. While moving with the system, the shoppers could be observed repeatedly switching gaze between the system and the environment at short intervals. This is likely part of an orienting activity, where the user samples the environment and the map to construct a more complete understanding of his/her physical context.

### DISCUSSION

The results obtained from our evaluation offer a strong indication that CaST was successful in acquiring user attention. The manner in which CaST kept that attention comes somewhat unexpected, however. We hypothesise that this phenomenon may be related to the complexity and stimulus intensity of the use environment. The gradual shift in focus from environment to system suggests an initial period of accustomisation followed by, in some cases, an almost complete surrender to favouring of the system‟s information over the individual‟s own faculties.

This supplanting of the shopper‟s perceptive efforts with the system‟s contextual information yields, according to our data, a lighter workload for the shopper. This lighter workload may play a large part in the shoppers‟ choice to concentrate so heavily on the system – if the information required is more easily available and equally correct from CaST, there is little reason to focus on the environment.

---

[2] This user had opted not to follow CaST‟s recommendations and was unable to obtain the location information of the product in question due to a usability-type error in the prototype.

Another explanation for this phenomenon could lie in the visually active nature of CaST. The orienting activity described earlier, where shoppers were seen rapidly switching visual focus between the system and environment can likely be attributed to the dynamic, continuously updating nature of the map component.

## CONCLUSION

We return now to the research question specified towards the beginning of this paper.

*"How can a context-aware shopping trolley be designed to acquire user attention?"*

Through the use of aural notification, CaST acquired user attention with a high degree of success. This assertion is founded in the visible impact the system had on its users when compared to those using traditional shopping tools. CaST was able to acquire its users" attention consistently, evidenced by their almost uniform product collection sequences compared to the randomness shown by the shoppers using the shopping trolley and paper list. The significant differences between the CaST users" and traditional shoppers" distance moved and mental workload figures also illustrate the system"s success in acquiring user attention.

In addition, the dynamic and continuously updating nature of CaST"s visual interface likely played a large role in maintaining possession of user attention throughout the test sessions.

## REFERENCES


1. Metro Group Future Store Initiative. www.future-store.org Future Store Rheinberg. *Viewed on Wednesday, June 07, 2006*
2. Schilit B. N., Theimer M. M. Disseminating Active Map Information to Mobile Hosts. IEEE Network 8(5), IEEE (1994), 22-32
3. Dey A. K., Abowd G. D., Salber, D. A Conceptual Framework and a Toolkit for Supporting the Rapid Prototyping of Context-Aware Applications, Human-Computer Interaction (HCI) Journal 8, Erlbaum (2001)
4. Schmidt, A., Beigl, M., Gellersen, H. W. There Is More To Context Than Location. Computers & Graphics (1999)
5. Dourish, P. What We Talk About When We Talk About Context. Personal and Ubiquitous Computing 8(1), Springer London (2004), 19-30
6. Cheverst, K., Davies, N., Mitchell, K., Friday, A., Efstratiou C. Developing a Context-aware Electronic Tourist Guide: Some Issues and Experiences. *Proc. CHI 2000*, ACM Press (2000), 17-24.
7. Skov, M. B, Høegh, R. T. Supporting Information Access In A Hospital Ward By A Context-Aware Mobile Electronic Patient Record. Personal and Ubiquitous Computing 10(4), Springer London (2004), 205-214
8. Bardram, J., Kjær, T. A. K., Nielsen, C. Supporting Local Mobility in Healthcare by Application Roaming Among Heterogeneous Devices. *Proc Mobile HCI 2003*, Springer Berlin (2003), 161-176
9. Lonsdale, P., Beale, R., Byrne W.Using Context Awareness To Enhance Visitor Engagement In A Gallery Space. *Proc. HCI 2005*
10. Griswold, W.G., Shanahan, P., Brown, S.W., Boyer, R., Ratto, M., Shapiro, R.B., Truong, T.M. Activecampus: Experiments In Community-Oriented Ubiquitous Computing. IEEE Computer 37(10), IEEE (2004), 73-81
11. Bohnenberger, T., Jameson, A., Krüger, A., Butz, A. Location-Aware Shopping Assistance: Evaluation of a Decision-Theoretic Approach. *Proc. Mobile HCI 2002*. Springer Berlin (2002), 18-20
12. Chalmers, M. A Historical View of Context. Computer Supported Cooperative Work (CSCW) 13(3-4), Springer Netherlands (2004), 223-247
13. Tamminen, S., Oulasvirta, A., Toiskallio, K., Kankainen, A. Understanding Mobile Contexts. Personal and Ubiquitous Computing, Springer London (2004), Volume 8, Number 2, 135-143
14. Dey, A.K., Barkhuus, L. Is Context-Aware Computing Taking Control away from the User? Three Levels of Interactivity Examined. *UbiComp 2003*, Springer-Verlag (2003), 149–156

## Appendix 2

Clemmensen, N.J., Black, D.J. Reducing Task Complexity by Dividing Attention: Exploring a Context-Aware Shopping Trolley. *Unpublished*

# Reducing Task Complexity by Dividing Attention: Exploring a Context-Aware Shopping Trolley

**Nils Jakob Clemmensen**
Department of Computer Science
Aalborg University
Frederik Bajers Vej 7e
Dk9220 Aalborg, Denmark
njay@cs.aau.dk

**Darren Black**
Department of Computer Science
Aalborg University
Frederik Bajers Vej 7e
Dk9220 Aalborg, Denmark
drdaz@cs.aau.dk

### ABSTRACT
From the field evaluation of an attention demanding context-aware shopping trolley (CaST), we have found that diverting shopper attention to a context-aware system can reduce the shopping task‟s complexity. Involving two configurations, an experiment with 18 participants has shown that users of CaST travel a significantly shorter distance compared to shoppers not using the system though they do not necessarily spend less time shopping. Our research has also shown that the demanding nature of CaST makes it easier for shoppers to find products and also makes them avoid having to backtrack in order to pick up products they had previously passed by. The findings from this study raise the question of how to balance attention demands to accommodate both shoppers and supermarkets.

### Author Keywords
Supermarket, shopping, context-awareness, location-awareness, divided attention, field evaluation, CaST.

### INTRODUCTION
The evaluation of a context-aware shopping trolley is the final part of an effort aimed at providing supermarket shoppers with a computerised tool to support the shopping activity. Modern supermarkets are designed to maximize sales through clever product placement, thousands of products to choose from, relaxing music and soft lighting, factors that all contribute to make shoppers buy more. These factors, perhaps by design, also add to the complexity of the environment by demanding attention, which can cause stressful shopping experiences [1]. By introducing a context-aware shopping trolley we hope to reduce complexity of the shopping task through divided attention. The goal of this paper can be surmised in the following research question:

“How can an attention-acquiring, context-aware shopping trolley support the shopping activity?”

To answer this question we have conducted 18 experiments (two configurations with 9 experiments in each) in a mid-sized Danish supermarket to collect data from the use of an active context-aware mobile system. The system used in this evaluation is a rich, functional prototype of a context-aware shopping trolley.

### RELATED WORK
The use of context-awareness has seen several applications within the area of mobile computing such as city guides [2], rendezvous planners [3] and similar mobile aides such as the ActiveCampus system [4]. Other efforts have concentrated on providing knowledge on how mobile systems are being used and how they affect their users [5, 6]. Research such as this provide valuable information on how to design a mobile application, evaluate it in the field and also predict the effects it will have when deployed.

Attention on the system as a factor in mobile computing has been researched by A. Oulasvirta et al. in a published article on how users on the move interact with mobile systems [5]. In this particular case the use of a regular (not context-aware) Smartphone with web-browsing capabilities was studied. 28 people participated in a field experiment where they had to complete 25 tasks while following a route through Helsinki, Finland, on foot and using public transportation. The tasks were all centred on searching the web using a Smartphone and to capture how the participants went about doing this several video sources were recorded. A two-way miniature camera was mounted on the Smartphone where it captured the participants‟ facial expression and all interactions with the Smartphone. Another camera was mounted on the participant‟s shoulder where it captured the participant‟s field of vision and furthermore a researcher was following each participant around with a miniature camera to capture the participant‟s environment. All three cameras carried by the user were wired to a recording device carried by the participant in a backpack. This backpack also contained a wireless receiver which recorded video from the researcher‟s miniature camera.

The results of this study suggest that users lend varying amounts of attention to mobile systems depending on their context. For example, in a laboratory setting the participants spent 16 seconds or more at a time paying attention to the Smartphone, while in more challenging situations such as walking with the device in a busy street this figure dropped to four seconds. These results tell us that users of mobile systems will usually pay varying degrees of attention depending on his/hers current context, something that can be analysed successfully through multiple video sources. However, we are not sure that a data collecting solution as complex as the one employed by A. Oulasvirta et al. is beneficial in all environments since carrying backpacks with multiple wires attached could make the participant too acutely aware of him-/herself to an extent that it could affect the experiment in an undesired way.

Unlike most applications context-aware systems have the ability to act on behalf of the user without requirering interaction. In their examination of user control of context-aware systems Dey and Barkhuus defines three levels of interactivity in mobile applications: personalization, passive context-awareness and active context awareness [7]. Personalization pertains to manual customization based on personal preferences while active and passive context-awareness are respectively a system updating on behalf of the user (active context-awareness) and a system prompting the user before updating (passive context-awareness). To find out what users thinks of these three forms of interactivity, a 5 day diary study with 23 participants was carried out. For the experiment the participants had to pretend that their mobile phones were capable of supporting both personalized and active/passive context-awareness services to aid them in 7 everyday scenarios. At the end of each day, each participant had to fill out a diary of how many times they would have used the services and to what degree they thought the services would have been useful. The resulting findings state that the participants generally preferred active context-awareness even though this made them feel less in control.

As a part of their work on designing a context-aware electronic tourist guide for the city of Lancaster K. Cheverst et al. evaluated a prototype of their system (called GUIDE) in the streets of Lancaster, focusing on the quality of the visitor‟s experience of using the system [2]. This effort consisted of two parts, an expert walkthrough of the system providing usability data and a four week field trial involving 60 participants. Data from this trial was gathered using direct observation, talk-aloud audio recordings, interaction-logs from the system and semi-structured interviews. Their findings showed that most participants enjoyed using GUIDE and found it to be trust worthy and easy to use. However, we can see that this approach does not provide data on how much attention the system required or the effects the system had on its users compared to tourists not using the system.

In their study of the effects a location-aware rendezvous planner [3], D. Dearman et al. used multiple evaluation configurations to capture the effects the system had on its users compared to participants not using the system. They had three groups of users completing the same tasks during three predefined rendezvous scenarios, one group using a mobile rendezvous planner, one group using cell phones and one group using both rendezvous planner and cell phone. Also, participant was given a map of the area in which they were supposed to arrange the rendezvous. Employing a „Wizard of Oz‟ approach for the groups using the rendezvous system, each experiment had two participants arranging several rendezvous while performing various tasks. Data from each experiment was collected via field notes, audio recordings of participants and the test leader, data logging, questionnaires and semi-structured interviews. D. Dearman et al. noted a number of shortcomings of this approach. First of all it was hard for the observer to note down interactions with the system (e.g. map glances) and second, the dynamic setting of the experiment as well as bonds between some participants made each experiment somewhat different from the others. Analysis of the gathered data showed that users of the system had an easy time of performing a rendezvous compared to the participants only using a cell phone. Furthermore the group using the system demonstrated different behavioural patterns compared to the group using cell phones which can be contributed to the introduction of the rendezvous planner.

The research commented in this section contributes knowledge on the fragmented nature of attention on mobile devices, user experience in context-awareness and how to evaluate mobile systems in the field. It does not however provide solid data on how demanding attention in a mobile context-aware system can lower task complexity, which is where we hope to contribute knowledge.

## METHOD

### The Experiment

In order to research how the use of CaST would divide attention and the effects this would have, we devised an experiment to replicate key aspects of a shopping trip in a real supermarket. To ensure realism, all tests were carried out at various hours when the supermarket was open to other shoppers. During the experiment, the supermarket staff gave their full cooperation and did not interfere with the tests in any way. This shopping trip and thus the experiment were based on the following scenario:

*A person has gone to a supermarket to shop for goods needed by his/hers household. To make sure that the shopping needs of all household members are covered this person has brought a shopping list that was previously hanging on the refrigerator. During the past week all family* *members have written down items they need, thus making the list somewhat randomized. Some of the products on the list are specific product names (Merci, Mors Stout etc) while others are more general (bread, eggs, bacon etc). The person who is now in the supermarket is familiar with most of the items on the list but he/she may be uncertain about some items, especially the some that have specific but unfamiliar names and others that are too general. After taking a shopping trolley, he/she now sets out to shop for all the items on the list. When all the items are found and placed in the trolley, he/she considers the job done since the only remaining part of the shopping trip is to pay for the goods and exit the supermarket.*

Since the shopping list is the central element of the scenario and the element that defines the task of shopping, the list used in this experiment was designed to be realistic as well as challenging. It includes common items, both edible products (milk, bread etc) and other items (sunscreen, sanitary products etc). We also included items that are purchased less frequently (HP ink cartridge, Chianti and a sieve). This shopping list was validated by all participants in the experiment. They all found it to be realistic although

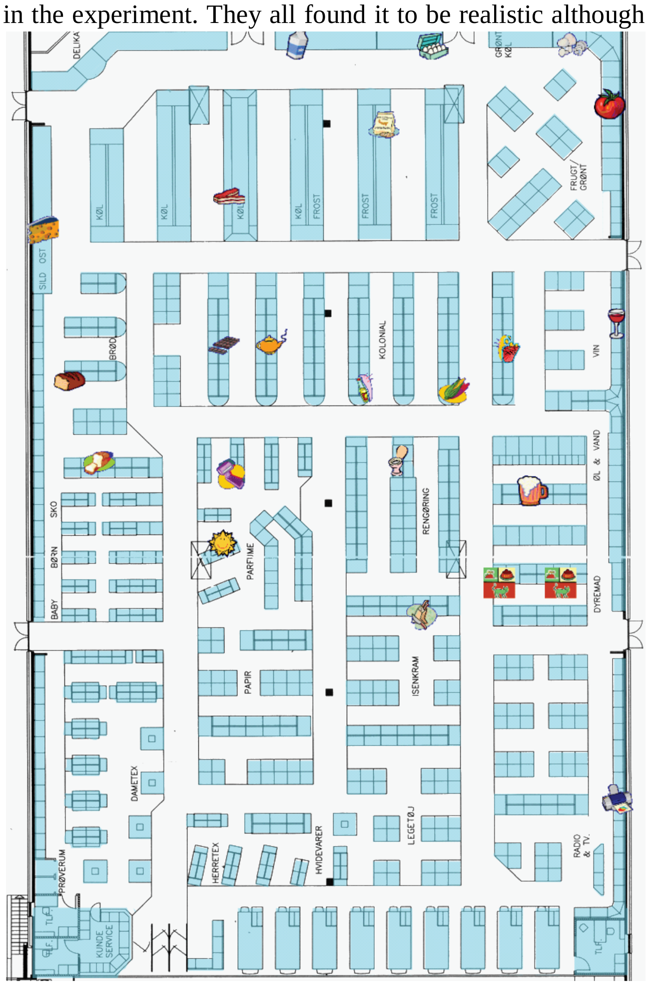


**Figure 2 A proportionally correct map of Føtex with icons showing the location of items shopped for in the experiment**

**Figure 1 In-store picture from Føtex**

many of them mentioned that they would usually not buy every item themselves (mainly cat food, ink cartridge and balsamico vinegar). Product placements can be seen in Figure 2 in the form of icons on a scaled down but otherwise precise map of the store layout.

### Setting

The Føtex supermarket in which this evaluation took place is part of a chain of medium-sized (by Danish standards) supermarkets. With a main shopping area of approximately 20.000 square meters this supermarket was chosen due to its size and wide assortment of products (food, cosmetics, electronics, clothing and wine). While being visually pleasant environment, the amount of shelves, advertisements, displays and product placements also makes Føtex a highly complex and dynamic environment, a photograph illustrating this complexity can be seen in Figure 1.

### Participants

18 participants were brought in as shoppers during the evaluation process, all of them on a voluntary basis without receiving any compensation. These 18 participants were divided randomly into two groups bearing the following statistics:

*CaST:* 9 participants (8 male and 1 female) ranging from 24-56 years of age (M=35.11, SD=13.79). 3 participants in this group shopped at least once per month in this Føtex store while 6 of them rarely or never shopped there. One of these participants did not own a computer and he also did not use one at work.

*Shopping list:* 9 participants (6 male and 3 female) ranging from 25-35 years of age (M=27.44, SD=3.57). 4 participants in this group shopped at least once per month in this Føtex store while 5 of them rarely or never shopped there. Only one of these participants did not own a computer and she did not use one at work either

**Figure 4 A test is commencing - the logger is simultaneously updating and logging the trolleys position while the test leader is overseeing the test**

While there are demographic differences between the two groups (in particular sex and age distribution), we do not believe that these differences had a significant bearing on the results.

### Procedure

To gather data suitable for comparative analysis, each session took one of two configurations; one using CaST and the other using traditional shopping tools (a paper shopping list, a pen and a trolley). The experiment was carried out in a similar way for both configurations.

In each session, the shopper undertook the task of collection the items on the shopping list. While this activity was under way, a test leader was present to elicit feedback where appropriate and a logger tracked the shopper‟s movement and product collections using the CaST control centre. After completing the experiment (which was considered to be complete when all the items on the shopping list were found) the participant was asked to fill out a questionnaire. The questionnaire included a NASA TLX test [8] which measures subjective workload. After completing the NASA TLX test each participant then gave a semi-structured interview. The two following sections contain specifics on each configuration.

#### *CaST*

After meeting with the participant he/she was given a short introduction of the CaST system and how it worked and a description of their task: Find the products on the shopping list embedded in the CaST system while thinking aloud about the experience in general. Should the participant need help using the system or help from store personnel to find products, they were told to ask test leader. Unlike the participants in the experimental configuration without CaST, we did not give the participants in this configuration any time to familiarize themselves with the items on the shopping list to ensure that they would be testing the system and not any prior knowledge or notion of where the products where located. Figure 4 depicts how the experiments involving CaST were carried out.

#### *Shopping List*

The purpose of this configuration was to obtain data for comparison with the CaST users‟ data. These sessions were to resemble a normal shopping trip, with the shopper using only a shopping list, a pen and a shopping trolley. The participants in this configuration was told to shop for a list of products like they normally would, while thinking aloud about the products they were searching for and how they would find them. They were also told, like the CaST users, that if they felt they would need help finding products that they should ask the test leader, in lieu of a member of Føtex‟s staff. Before beginning the experiment they were given approximately two minutes to familiarize themselves with the shopping list and rearrange it if they felt it necessary (all shoppers used the time looking at the list, but none rearranged it).

### System Description

The CaST system is a trolley-mounted prototype designed to help shoppers find the items on their shopping list (see Figure 3). The system‟s user interface and input device are presented through a trolley mounted touch-screen.

Using context-awareness the system can help shoppers navigate using a location-aware map and a shopping list ordered by proximity. The shopping list shows the name of the product and a small icon representing the product. CaST is designed to acquire user attention when important updates occur. Using audio channelled through a Bluetooth headset, the system plays back sound to draw attention if a product on the shopping list was near by. An image of the nearby product is also shown, to support product recognition and help the user to pick up the correct item. CaST features a map that moves and updates according the system‟s current location. This map contains icons

**Figure 3 A picture of the touch screen mounted on CaST**

representing products (the icons match those in the shopping list) and these icons are highlighted based on their proximity to the system.

### Data Collection

Multiple means of gathering data were used for both configurations. Audio was captured from small digital mp3 audio recorders worn by the participant and the test leader, and finally the logger continuously captured position and product collection data using a custom made Pocket PC-based logging application. To ease the task of synchronising these data sources a marker sound was played back by the logging application when it started logging data. In the CaST tests, video of the shoppers‟ interaction with the system was captured by a camera mounted at the front of the trolley. Also, the number of times each participant asked for assistance was noted down by the test leader.

The logger continuously plotted in the participants‟ current location on a digital map and also marked when products on the list were picked up. These data were automatically written to a file which contained coordinates and the names of the products that were taken. Both the coordinates and the products were written sequentially and were also marked with a timestamp to allow performance measuring during analysis. During the tests involving CaST this application was also used in a Wizard of Oz [3] fashion to simulate the context awareness features of CaST such as location awareness, proximity to products and awareness of trolley contents. This approach can be seen in Figure 4.

Having collected all the products, the shopper was given a questionnaire to complete. This questionnaire was designed to provide data related to: demographics, proficiency with technologies such as mobile phones, PDA‟s, computers and GPS, shopping habits such as how often they brought shopping lists and used trolleys, how easy it was to find products and if they used signage or labels to find products. In addition to these questions, CaST users had to fill out an extra page containing questions relating to use of the system while shopping for products. All the participants completed a NASA TLX test to provide subjective workload data from the experiment. The session concluded with a semi-structured interview.

### Data Analysis

The gathered data were analysed over a number of parameters. Student‟s t-test and Fisher‟s exact test were applied to test for statistical significance where applicable:

Distance travelled: Using coordinates from the logging application we were able to calculate the distance travelled by each participant to pick up all products.

Route Through the Supermarket: Each shopper‟s route through the supermarket was retraced, drawn on a map and then analysed for patterns specific to each group.

Performance: Measuring performance was done in four ways: total time spent finding products, time spent between each product, the number of times asked for help and subjective opinions (from the data collected in the questionnaires) of how easy it was to find the products.

Product Collection Sequence: The order in which the shoppers collected the products was analysed in a group-wise fashion to highlight differences between the two groups.

Subjective of CaST and Workload Assessment: The results of NASA TLX were processed in order to obtain a subjective workload measure for all the shoppers. The results from each group were then compared. From the questionnaires and the interviews we also assessed what the group using CaST thought of the system as a whole and what they liked/disliked about it.

## RESULTS

Thorough analysis of the data gathered provided the following results.

### Distance Travelled

Looking at the results in Table 1 it is evident that the group using CaST travelled a shorter distance compared to the other group. In average the participants using shopping lists had to cover 107.4 more meters than the participants using CaST. This is an increase of 31.8% and is statistically significant ($t(16)=-4.087$, $p<0.001$).

Throughout the experiment we found that the participants using shopping lists had to backtrack in order to get products they had previously been close to. It appears that the cause of backtracking was that the shoppers without CaST could not maintain a mentally ordered shopping list. Our data show that these participants often passed within metres of products they had to pick up when they were focusing on other items or if they got distracted. One participant did this to a great extent. As an example he forgot to pick up chocolate which caused him to backtrack a distance equivalent to half the length of the store at a point where he was almost done getting the products. This backtrack and others like it caused this participant to walk 785 meters which is 54% further than the participant who covered the least distance, 422 meters using CaST. 6 out of 9 participants using the shopping list actually had to backtrack in order to pick up the chocolate adding approximately 85 meters to the distance they had to walk. Similar backtracking also happened to two CaST users when they went against the systems recommendations. Ignoring the system‟s routing recommendations brought

| | CaST | Shopping list |
|---|---|---|
| Distance | 469.12 (±55.53) | 618.28 (±94.37) |

**Table 1 Average distance walked in meters**

these users away from the optimal route determined by the system. This course of action usually led to some backtracking though this was somewhat less problematic since the system was able to provide an indication of the products" placement.

For the shoppers using traditional shopping tools, backtracking was caused both by the complexity of the environment, and occasionally incorrect presumptions about the layout of the store. Many of these participants said that they thought that most products would be located near similar items. One shopping list participant, while searching for a specific product, said: "When searching for the maize grits I instantly looked for baking goods since this is where the grits fit in – if not there, then they"ll be near the cereals." This presumption was wrong and caused her to walk back and forth between baking goods and cereals before finally giving up and ask for help. Her focus was on finding the maize grits and her attention was limited to searching areas where the product in question could not be found. In the course of her searching, she walked right by the maize grits several times without noticing.

Users of CaST on the other hand did not have to pay attention to their immediate environment to look for products. CaST"s notification system proved effective, as we saw no instances of users passing by products without indicating that they were aware of their presence. Since a picture of the nearby product would also be shown at the point of notification, the CaST users were able to recognise the product, and knew, after having looked at the map, where to look for it.

### Route Through the Supermarket

The differences in how far the two groups of shoppers walked are also present when looking at the routes they took through the supermarket. The shoppers" routes through the store can be seen in Figure 6 and Figure 5. As can be seen in these figures, the shoppers using traditional tools took a greatly varied route, covering areas which were not task-relevant. In contrast the routes taken by participants using CaST are relatively uniform, as can be seen in the comparative lack of „stray" individual lines in the figure representing CaST users.

The reason for this is the same that caused participants using CaST to travel a shorter distanced – they pay

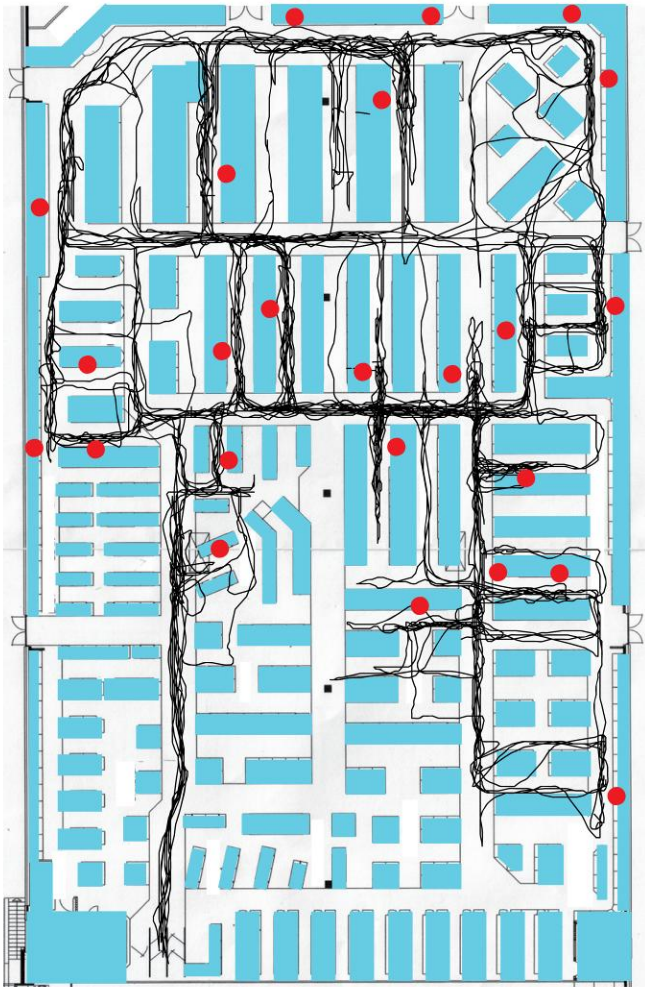

**Figure 6** **CaST participants' routes**

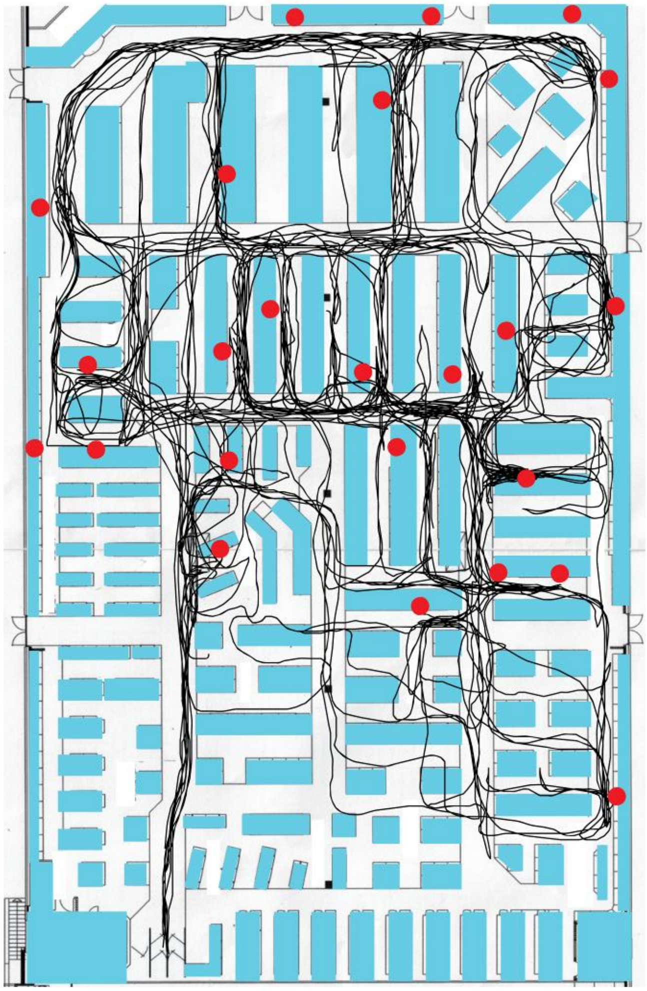

**Figure 5** **Shopping list participants' routes**

attention to the systems recommendations and tend to follow them which more or less cause them to use the same route through the store.

While this does not prove that the participants using CaST used a more efficient route it does suggest that participants using shopping lists were searching for products in more places and also backtracked more than the participants using CaST.

**Performance**

From the timestamps we have found that CaST participants in average spent 28:49 (SD=07:07) while the shopping list participants spent 29:58 (SD=05:10). This difference is not statistically significant (t(16)=-0.392, p=0.700) but nevertheless interesting. In average the group using CaST spent almost as much time to complete the experiment as the other group even though they only had to walk 2/3 of the distance.

The CaST participants generally spent time standing still and attending to the system before and after a product was located – examining the product‟s appearance/position, and checking the shopping list for the next product to collect, respectively. The CaST users also divided their attention between the system and the environment while moving, evidenced by repeatedly switching gaze. We believe this to be part of an orienting activity, where the user samples the environment and the map to construct a more complete understanding of his physical context.

When looking at the individual performances another result emerges. The fastest participant (who used CaST) spent 18:31 completing his shopping which is 05:14 faster than the fastest participant using a shopping list, who spent 23:45 to complete the shopping trip. The slowest time was also found among the group using CaST since a CaST user spent 39:12 opposed to the 37:55 it took the slowest participant using a shopping list to complete the shopping trip. Interestingly this participant did not travel markedly longer compared to the other CaST users while the slowest participant using a shopping list was also the one who travelled the longest distance. In the video of slowest participant using CaST it could be seen and heard that he was having major problems navigating using the map since it did not rotate, something all users of CaST suffered from to some extent.

*Asking for help*

Another performance measure used was to compare the number of times the participants from each group had to ask for help to find a product. This happened 1 time for the group using CaST and 33 times for the other group which a Fisher‟s exact test shows to be highly significant (p<0.0001). The participants not using CaST generally had big problems finding the right products and these problems generally occurred when searching for the same items. The audio and video data show that the participants using CaST did not experience these problems since they paid attention

| | |
|---|---|
| **CaST** | 17.13 (±2.38) |
| **Shopping list** | 20.30 (±8.18) |

**Table 2 Scoreboard of how hard the groups in average thought it was to find products. The higher the score the harder it was for the group to find all the products**

to the system. The aspect of CaST that really seemed to help them was the pictures that were automatically shown of a product when the participant got near. All participants in this group found this feature to be extremely useful though a few of them mentioned that they would like to get a picture of the products placement on the shelf since this would in some way add depth to a products‟ position on the map. The one time a participant using CaST asked for help locating a product was when one of them had purposefully ventured away from a product in pursuit of another one he intuitively thought would be faster to get. After getting that product he could not find his way back to the product he had just left behind. The reason for this was that CaST currently does not provide any indication of a product‟s location if it lies outside the map‟s display area.

*Ease Of Finding Products*

Based on the participants subjective opinion of how hard it had been to find each product Table 1 was calculated using scores derived from the questionnaires.

For each item on the shopping list the participants could answer if it was "Very easy – Easy – N/A – Hard – Very Hard" to get that specific item. In order to calculate numbers of how hard it had been to pick up product, a number of points were assigned to each answer, so that "Very easy" was assigned 1 point while "Very hard" was assigned 5 points. To get an overall measure of how hard a participant thought it was to pick up all the products the average score was calculated – the higher the value the harder it was to find all the products.

The scores show that the group that did not use CaST generally had a harder time finding products. Though the statistical difference between the two sets is not significant (t(22)=-2.022, p=0.056 from a paired Student‟s t-test) a closer inspection of the questionnaire results show that the participants had a significantly harder time finding 5 specific products. For these products, the score was at least 10 points higher for the group using shopping lists. Furthermore these scores match the time it took for the participants using shopping lists to find them and these products were also the ones they had to ask for help finding (accounting for 30 out of the 33 times this group asked for help).

**Product Collection Sequence**

Within each group we analysed the sequence in which the products were collected. This analysis provided interesting patterns for both groups and these are depicted in the graphs

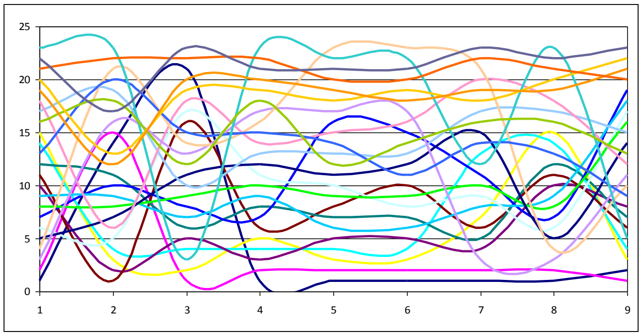

**Figure 7 Graph of the sequence in which the products were collected by the group using a shopping list**

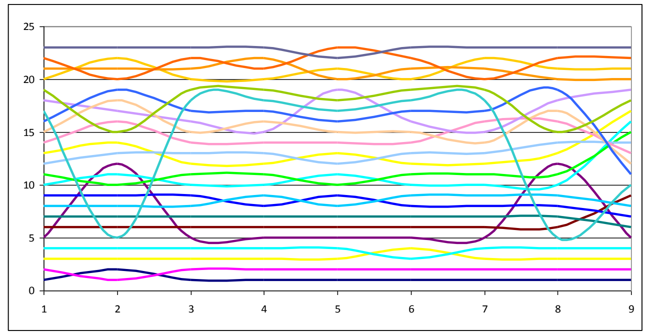

**Figure 8 Graph of the sequence in which the products were collected by the CaST group**

shown in Figure 7 and Figure 8. Each line in the graphs represents a product and the way this line curves shows the difference in the order it was collected (i.e. if all shoppers in the group collected product x as the nth item in the collection sequence, the line representing this product would be horizontally straight). This holds true for all the products in both configurations so that if all products were picked up in the same order by all participants in each group, there would be nothing but straight lines in both graphs.

Since the lines in Figure 8 are generally straighter than the lines in Figure 7 it appears that the users of CaST picked up the products in more or less the same order as the participants in this group. The same does not hold true for the group not using CaST illustrated by the extremely significant difference ($p < 0.0001$) in how often each the participants in each group picked up products in the same order (see Table 3 Fisher's exact test of when products were picked up in the same order yields high significance ($p<0.0001$).)

We suspect that patterns showing in the order in which the CaST group picked up products were caused by the route implemented in the system, and the willingness of this group to follow the system‟s directions. When asked why they were picking up one item instead of another all participants using CaST said that they did what the system told them to do.

### Subjective Workload Assessment

The results from the NASA TLX tests while inconclusive point towards that CaST lowers its users‟ perceived workload when compared to the group that did not use CaST. As can be seen in Figure 9 the overall perceived workload was approximately 28% lower for the participants using CaST compared to those who used pen, paper and a regular trolley. Statistically the difference between the two groups TLX scores is not significant ($t(16)=-1.842$, $p=0.084$) but the scores for mental workload ratings are ($t(16)=-2.292$, $p=0.036$). The lower mental workload reported by the users of CaST suggests that divided attention and context-awareness caused them to waste less mental efforts on finding the products.

| | In order | Out of order |
|---|---|---|
| **CaST** | 131 | 76 |
| **Shopping list** | 79 | 128 |

**Table 3 Fisher's exact test of when products were picked up in the same order yields high significance (p<0.0001)**

From the questionnaires and interviews, we found that the participants generally liked shopping using CaST and thought that it had a positive effect on shopping. When rating their shopping experience using CaST, 1 answered „very good‟, 5 answered „good‟, 2 answered „NA‟ and 1 answered „less good‟. The one participant who answered „less good‟ said that he would rather explore the shop himself. We also asked the other eight participants to comment their answer and the two answering „NA‟ said they were afraid of the system ruining their shopping experience at times when they would like to browse the store at leisure. The six participants who answered „very good‟ or „good‟ said that CaST improved their shopping

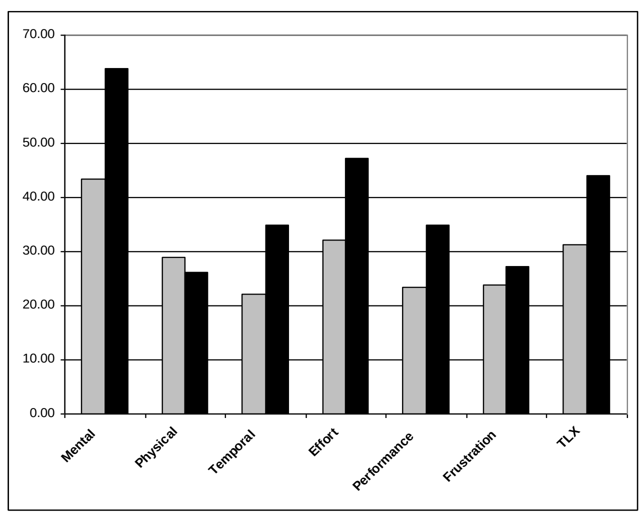


**Figure 9 Raw TLX ratings and weighted TLX scores**

experience since it made shopping faster and easier.

## DISCUSSION

Based on the results it is clear that the attention demanding nature CaST changed the way its users shopped for the products on their shopping lists. The question now is whether these changes are desirable or not.

### Divided Attention and Context-Awareness in Supermarkets

The results from that were obtained from this experiment suggest that context-awareness and attention aquisition can be used successfully to reduce the complexity of an otherwise complex environment. In the retail area however, this is not necessarily mutually beneficial for shoppers and supermarkets.

As noted in [1] supermarkets design their retail environment to maximize sales using offers, colourful signage, soft music and appealing displays but the CaST users did not seem to notice. When asked, none of them had noticed any specific products displayed in the store other than the ones they shopped for, clearly not something any supermarket would want. However, the high level of attention on the system can utilized by the supermarket since it enables them to control which products and offers a shopper will be exposed to during shopping. Also, using context-awareness to gather data on shopping patterns, preferences and a new form of advertising could be introduced in stores.

The reason for CaST reducing complexity of the shopper‟s context is that it lessens the need for attention to the environment. Therefore, should supermarkets choose to deploy a system similar to CaST and use it to advertise products in a disruptive manner, or in other ways interfere with a user‟s shopping experience, the system will likely prove less effective. If the very same features that enable CaST to divide user-attention are used to promote products or services it could reintroduce the complexity that CaST shields its users from from, negating its usefulness. A parallel can be drawn to pop-ups on the World Wide Web. Even though users perceive them as annoying and distracting, studies have shown that they are effective nonetheless [9], a fact that could very well tempt supermarkets.

Another factor is a user‟s willingness to release control to a computer system. In GUIDE, [2] this was not a problem since the users saw the benefits the system gave them and other studies have shown that users do not mind putting a system in control as long as it is beneficial [7]. Similarly, in our evaluation, all CaST users could see the benefits of letting the system guide them, drawing their attention away from the environment, since they felt it made shopping easier. Six of the CaST users said they liked being able to get their products this way since they did not have to pay attention to product placements, signs and advertisements that both stressed them and made them spend money on products they did not really need. Three of them did, however, express concerns about the system possibly causing them not to discover products they would otherwise be interested in buying.

### Oddities Observed During the Tests

While this experiment was carried out, we noted a number of oddities that could possibly both be causing erroneous results or be findings in their own right.

When going about their shopping participants using a shopping list sometimes picked up products that we did not intend for them to pick up. Also, some participants found products at places where they, to our knowledge should not be. In retrospect these two oddities are not sources of error since the participant just did what the shopping list told them to. They simply picked up the products that felt right to them since the list did not specify if i.e. the mushrooms should be fresh or placed in a jar. Similar incidents did not occur during the tests involving CaST since the participants obeyed the system when picking up a product. They simply did not consider other products than the ones embedded in the system and if a product could be found in more places they never noticed.

## CONCLUSION

The purpose of this paper was to explore how the attention demanding CaST prototype would support the shopping activity, and a field experiment has yielded the following results.

The introduction of CaST and the attention demanding nature of the system resulted in shoppers travelling a shorter distance compared to participants not using CaST. In general, users of the system did not spend significantly less time completing the test but since they had attention on the system they could find products easier and they also required significantly less help to locate products. Paying attention to the system also helped CaST users avoid having to backtrack. These results show that users of CaST were less affected by the complexity of the environment, since it was easier for them to find products while their perceived mental workload was significantly lower than the participants using shopping lists. The results also show that CaST was successful in dividing attention, since CaST users usually gathered products in the same order, something that shopping list users did not.

Of the nine participants using CaST, 6 of them thought that CaST had a positive effect on shopping, two of them did not know and one participant felt that the system caused a less positive shopping experience. The three participants, who did not know or thought that the effects of CaST were not positive, felt that it took too much attention away from the shopping environment.

These results do not show how attention demanding context-aware systems general would perform in complex environments since CaST is specifically designed for shopping in Føtex. Also, though CaST shows promise in many ways it is still not clear how the level of attention it requires should be managed to suit shoppers and shops alike and this will require further research.

### Limitations

The tests were carried out during weekdays and at different hours. This resulted in varying crowd density though the two groups perceived it to be almost the same judging from the questionnaire. When asked however, 5 CaST participants said that they did not really notice how crowded it was.

Many of the results are based on the coordinate data and as such the validity of these are very important. When counting incidents where participants appear to have crossed shelves on a map with all the routes plotted we have found that 52 of the 5467 coordinates logged were faulty. This means that 0.95% of the coordinates were logged faultily, a small enough number to be statistically insignificant.

The participants using CaST were being filmed on video while theirs tests commenced while the shopping list users only had their speech recorded. After the test we asked each CaST participant how they felt about being video taped they all said that they had not felt it affect their behaviour since CaST usually took their attention. Two participants also said that they would have felt differently about being video taped had they not been using CaST.

### Further Work

With the potential of having pop-ups and similar dubious ways of advertising to a completely exposed shopper, we can only speculate if a full-scale introduction of a system similar to CaST will be beneficial to both supermarkets and shoppers. Clearly more research needs to be done in this area since this technology needs to be balanced in order to be beneficial for both parties. Research has been done on advertising in pervasive computing [10] but the effects of advertising through context-awareness and divided attention is still not explored.

### REFERENCES


1. Aylott, R., Mitchell, V.W. An exploratory study of grocery shopping stressors. International Journal of Retail & Distribution Management (1998), 362-373
2. Cheverst, K., Davies, N., Mitchell, K., Friday, A., Efstratiou C. Developing a Context-aware Electronic Tourist Guide: Some Issues and Experiences. *Proc. CHI 2000*, ACM Press (2000), 17-24.
3. Dearman, D., Hawkey, K., Inkpen, K. Effect of location-awareness on rendezvous behaviour. *Ext. Abstracts CHI 2005*, ACM Press (2005), 1929-1932.
4. Griswold, W.G., Shanahan, P., Brown, S.W., Boyer, R., Ratto, M., Shapiro, R.B., Truong, T.M. ActiveCampus: Experiments in Community-Oriented Ubiquitous Computing. Computer, IEEE Computer Society (2004), Volume: 37, Issue: 10, 73- 81
5. Oulasvirta, A., Tamminen, S., Roto, V., Kuorelahti, J. Interaction in 4-Second Bursts: The Fragmented Nature of Attentional Resources in Mobile HCI. *Proc. CHI 2005*, ACM Press (2005), 919-928
6. Tamminen, S., Oulasvirta, A., Toiskallio, K., Kankainen, A. Understanding Mobile Contexts. Personal and Ubiquitous Computing, Springer London (2004), Volume 8, Number 2, 135-143
7. Dey, A.K., Barkhuus, L. Is Context-Aware Computing Taking Control away from the User? Three Levels of Interactivity Examined. *Proc. UbiComp 2003*, Springer-Verlag (2003), 149–156
8. Hart, S.G., Staveland, L.E. Development of the NASA-TLX (task load index). Human Mental Workload, Elsevier Science Publishers (1988), 139-183
9. Edwards, S. M,, Lee J. H., Li, H. Forced Exposure and Psychological Reactance: Antecedents and Consequences of the Perceived Intrusiveness of Pop-Up Ads. Journal of Advertising vol. 31, 2002, M.E. Sharpe Inc. (2002)
10. Ranganathan, A., Campbell, R. H., Advertising In a Pervasive Computing Environment. Proc. of the 2nd international workshop on Mobile commerce 2002, ACM Press (2002), 10-14

## Appendix 3

Excel spreadsheets of the data gathered during the evaluation can be obtained from: **www.cs.aau.dk/~njay/appendices.rar**

Should the appendices for some reason not be available, please forward your request to njay@cs.aau.dk