Applying Pervasive Technologies to Create Economic Incentives that Alter Consumer Behavior

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ABSTRACT

Economic incentives are a powerful way of shaping consumer behavior towards more commercially efficient and environmentally sustainable patterns. In this paper, we explore the idea of combining pervasive computing techniques with electronic payment systems to create activity-based micro-incentives. Users who consume additional resources by e.g., occupying an air-conditioned space instead of a normal space are levied additional micro-payments. In an alternative approach, consumers who choose to save resources are rewarded with micro-rebates off the price of a service. As a result, the cost of using a service corresponds more closely with the resources used, leading market mechanisms to allocate resources efficiently. A key challenge is designing incentive mechanisms that alter consumer behavior in the desired fashion. We introduce four incentive models, and present evaluation results suggesting that consumers make different decisions depending on which model is used.

Author Keywords

Persuasive technology, economic incentives, mobile payment, micropayments, activity-based micro-pricing, virtual currency

ACM Classification Keywords

H.1.2 Models and Principles: User/Machine Systems.

General Terms

Design, Economics, Experimentation, Human Factors

INTRODUCTION

Two emerging topics in pervasive computing and HCI research are persuasive applications and electronic payment systems. Pervasive persuasive applications seek to alter user behavior through the means of a feedback loop between sensor-tracked user behavior and system output [14, 15, 17]. In many cases the aim is to encourage environmentally responsible behavior. In electronic payment systems, pervasive technologies have been used to implement and deploy mobile payment solutions that enable small payments in a discreet and effortless manner [9]. In this paper, we combine these two topics, exploring the possibility of using pervasive computing technologies to create small activity-based economic incentives that discreetly steer consumer behavior towards desired patterns. Applications for such technology can be found both in business as well as in resource conservation.

Free resources shared by a number of people, such as a public toilet or the natural environment, tend to be overused in a process called the tragedy of the commons [4]. This happens because each individual derives a personal benefit from using the resource, while any costs are shared between all the users, leading to inconsiderate use. An example of such behavior is the wasteful use of free plastic shopping bags that are filling landfills. A common strategy to dealing with the tragedy of commons is to impose a tax on the use of the resource. In Japan, plastic bags are usually free, but in Finland shoppers have to pay for them. This provides an economic incentive for individuals to re-use shopping bags. This kind of economic incentives have been found to be a powerful way of persuading people to change their behavior.

However, vendors and regulators are currently limited in what behaviors they can set a price on. Only a limited range of consumer activities can be feasibly observed in a limited number of locations (e.g., at the cashier in a store). Sometimes manual observation is used to enable complicated activities to be priced (e.g., using a plastic bag vs. bringing one's own shopping bag), but the cost of human resources imposes a limit on this approach. If activities could be recognized with less cost, activity-based micro-pricing would become possible in a great range of application areas. Some of these applications could be aimed towards preventing overuse of environmental resources, while others would simply enable businesses to charge for their services in a more fine-grained manner, overcoming inefficiencies and stimulating commerce [1].

On the other hand, real consumer behavior does not fully conform to the economic expectations of rationality. In our previous work on mobile payment systems, we found that the consumer's emotional response to the payment system was an important factor in economic behavior [8]. This topic area has been studied extensively in the field of economic psychology, where certain predictable patterns such as risk-aversion have been identified. In this study, we draw on findings in economic psychology to propose four basic incentive models for activity-based micro-pricing. Our experimental

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studies suggest that consumers make different decisions depending on which of the incentive models is used, even when the total economic impact is the same. This implies that activity-based micro-pricing systems can make services persuasive by simply changing transaction flows, without necessarily altering total amounts. In an experiment with a prototype of the billing system we also identified a number of issues that must be addressed in future research.

In the following sections, we describe the concept of activity-based billing systems and discuss how economic incentives affect a consumer's decision making process. We then present an overview of a system architecture for an activity-based billing system that supports four different incentive models. Each model corresponds to a different set of transaction flows, so that services can alter consumer behavior by choosing a different model. Then, based on user evaluation and lessons learned in the prototyping process, we discuss the feasibility of the concept and the main research challenges that remain.

ACTIVITY-BASED BILLING SYSTEM

Ubiquity of Payments

The rapid growth of mobile computing has transformed mobile devices to a medium of payment. Mobile devices are used to initiate, activate and confirm payment transactions in various kinds of services, collectively known as "mobile payments" [16]. Mobile payments are not simply an extension of normal electronic payments, as they free users from physical constraints (i.e., time and place) and allow flexible decision making that adapts to the mobile use context [10].

While new features have been added to mobile user terminals, our surrounding environments are also increasingly being embedded with ambient intelligence. To support daily tasks and events, living environments are expected to become sensitive to the presence of users. For example, elder people's activities might be monitored with sensors in order to automatically detect emergency situations. Thus computers, sensors and network connectivity have been installed into buildings, parks, trains and everyday objects [7].

The maturity of mobile payments and the increasingly prevalent ambient intelligence technology suggest the notion of *ubiquitous payments*. As argued in [3], sufficiently fine-grained tracking of user activity makes it possible to implement accurate pay-per-use payment models in commercial services. With sufficient context information, vendors can precisely calculate the economic cost of a consumer's action, and bill accordingly. Ubiquitous interaction techniques give consumers real-time information and control over spending. Transactions of small nominal value take place frequently, since payment is associated with consumer actions. In ubiquitous computing environments, payments become ubiquitous, too.

In this section, we introduce the idea of activity-based billing systems. Figure 1 illustrates an example scenario with two types of transaction flows, case A and case B.

Pricing Consumer Actions

A common problem for managers of busy cafe and restaurants is that customers linger in the space for a long time after their initial order without placing any additional orders, whilst taking up space from other potential customers. It is difficult to keep track of how long each customer has stayed without making some effort to monitor them. Moreover, it would be troublesome for the staff to collect a fee for the overstay even if such customers could be identified accurately. As a result, limited seats remain occupied and from the manager's point of view, resources used inefficiently.

If the cost of customers' time spent in the cafe could be automatically priced, the situation would be different. Consider a billing system that notifies customers how much they have to pay for spending time in the space: "An additional fee will be charged for further stay: \$0.1 for every 10 minutes", for instance. If the customer continues to stay despite the notification, the system begins to charge the time on their mobile phone. In this way, the manager can charge an additional fee from overstaying customers, improve the availability of seats with recouping the cost of lost business from the occupied seats (case A). On the other hand, it is also possible to give rebates to customers who take actions that are beneficial to the business. For example, coffee price can be reduced if a customer orders coffee to go in lunchtime (case B).

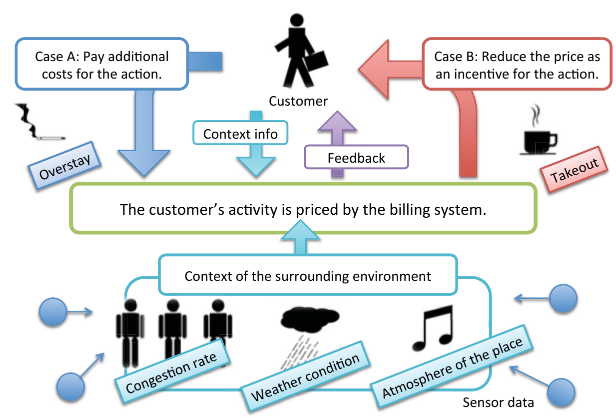

Figure 1. Activity-based micro pricing

Our key idea in this scenario is coupling economic incentives with specific actions, and implementing the resulting incentive system using ubiquitous computing technologies. Context recognition techniques provide support for tracking consumers' actions. The payment or rebate can be carried out smoothly by mediating it with a mobile payment system. Furthermore, different pieces of context information can be used by the vendor to determine the current price of a given action. If the overstay charge increases as the cafe becomes increasingly packed, it will motivate customers to move on speedily. The occupancy rate of seats can be manually checked, or automatically detected with pressure sensors embedded in chairs. Methods such as discount coupons and selective taxation are sometimes used for creating economic incentives that steer consumer behavior, but compared to the approach outlined above, they are inflexible and static.

Psychological Factors in Incentive Design

The price of an action should be based on the characteristics of the action as well as the desired incentive effect. In the example scenario, the cafe charged an additional fee for overstay at every 10 minutes, since staying is a continuous state of action. On the other hand, taking out a coffee is a one-time action, after which the customer departs from sphere of the service. The rebate for this action is therefore only conducted once and the sum is higher than in the continuous payment case.

The prices of these actions will nevertheless be relatively small compared to the price of, for example, a cup of coffee, because the incentives are not a core part of the service. Under the notion of ubiquitous payments, transactions happen anywhere, anytime a consumer takes a relevant action. This leads to an increase in the frequency of transactions, and the price per one action will correspondingly decrease. Thus in the activity-based pricing mechanism design, we must consider how to affect consumers' behavior with stakes of relatively low nominal value.

It is well recognized that consumers' real economic behavior is emotional and sometimes leads to irrational decision making [2, 11]. In some cases this lack of economic rationality follows quite predictable patterns. For example, people tend to avoid risk associated with uncertain gains. If there are two choices, such as (a) receive a guaranteed sum of $10, and (b) receive $20 with a 50% probability, choice (a) is preferred even though the expected utility is same. While risk-neutral and risk-loving attributes also exist, this preference that most people have is called risk-averse. Risk-averse decision making results from so-called loss aversion bias explained in *prospect theory* [6, 18].

According to prospect theory, an individual's value function for any kind of gains and losses takes the shape of an asymmetric S, as illustrated in Figure 2. Variable U does not represent actual gains or losses in money, but the utility that a consumer perceives. A floating reference point divides the value range of gains and losses into positive and negative segments. If variable x is negative (representing a loss), the slope of the curve is steeper than in the positive (gains) case. Thus the absolute value of $f(-\alpha)$ is greater than $f(\alpha)$, indicating that people experience greater impact from losses than from correspondingly large gains. This leads to the observed loss-averse behavior.

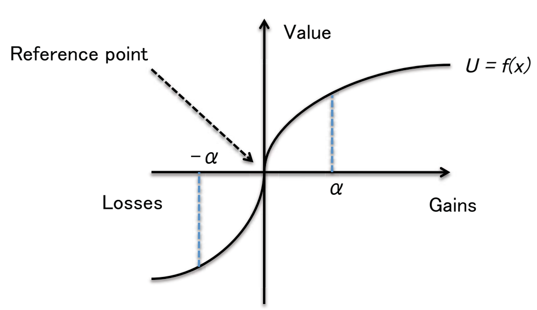

Figure 2. A hypothetical value function in prospect theory

The practical implication of this asymmetry for economic incentive systems is that surcharges (losses) and rebates (gains) can be used to create different kinds of incentivizing effects even when their overall economic impact is the same. For example, during busy lunchtime hours, a cafe could charge patrons in the form of a small initial fee and additional time-based surcharges, encouraging short stays. During quieter hours, when the manager wants patrons to linger for as long as possible, the equivalent sum could be charged in the form of a bigger initial fee and tiny time-based rebates. The suitable model can thus be chosen according to desired behavior. The graph also shows that the marginal increase or decrease in perceived value diminishes as variable x goes further from the reference point. This suggests that a well-designed incentive system can realize disproportionately large incentivizing effects with trivial sums of money.

In behavioral psychology, an important factor in effecting behavioral changes is the timing of feedback. Immediate feedback is superior to delayed feedback, and suitable scheduling can be used to enhance the effect further. In activity-based micro-pricing, calm feedback methods can be used to inform customers in real time of micro-payments and rebates that are being conducted as a consequence of their actions. Notifications of time-based charges can be conducted at suitable intervals.

SYSTEM ARCHITECTURE

In this section, we describe the system architecture of the billing system (Figure 3). The system is composed of user side modules and service side modules.

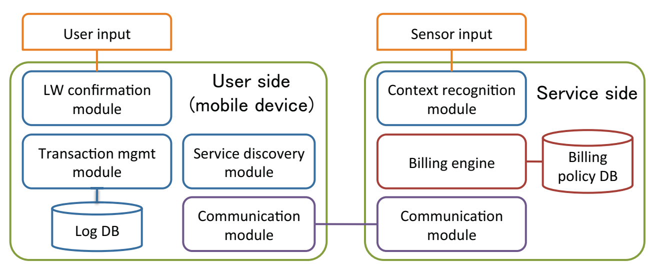

Figure 3. System architecture of the billing system

User Side

Consumers are assumed to have a mobile device for communicating with services and conducting transactions. The transaction management module handles transactions, such as charges, payments and rebates. The module also records all transactions into a database called Log DB, which can be used for error recovery. The service discovery module detects available billing systems within range of the device's wireless connectivity (e.g., WiFi, Bluetooth). The communication module establishes a connection to the detected billing system and encrypts data before transferring it to the service.

The LW confirmation module stands for "Lightweight confirmation". Since activity-based transactions happen frequently, each transaction should impose minimum cognitive load on the consumer. Traditional PIN-number based payment confirmation steps are too heavy; instead, the lightweight confirmation module allows consumers to approve payments using simple gestures, such as tapping the device twice, without even removing it from the pocket. Moreover, a completely automatic payment mode with no user approval steps could be feasible if the system is sufficiently trustworthy and the sums at stake minimal. We will return to this cognitive transaction cost issue in more detail below.

Service Side

The billing system must recognize consumer's activities within the scope of the service in order to price and bill the behavior, and provide feedback. The context recognition module handles inputs from consumer's devices as well as sensors that are installed in the environment. Context information required by the billing engine is generated by pre-configured sensor analysis algorithms. The billing engine gathers the necessary context information and consumer's personal information, where necessary. The service's billing rules are pre-configured into a database called the billing policy DB; the engine calculates the applicable payment or rebate amount according to the policies set in the DB.

The key challenges in implementing the system are designing an effective context recognition module and suitable billing policies that lead to desired incentivizing effects. In the following sections, we will build on the earlier discussion on economic incentives to introduce four basic micro-pricing models that can be used as the basis of such policies.

FOUR BASIC MODELS OF MICRO-PRICING

In this section, we introduce four basic models of activity-based micro-pricing. The models consist of simplified transaction flows, and each one represents different incentive design. Thus it is possible to replace, combine, and switch the models according to a vendor's objectives.

UbiPayment Model

As illustrated in Figure 4, the UbiPayment model is used to charge additional costs upon consumer's specific actions. This transaction flow corresponds to the case A in Figure 1.

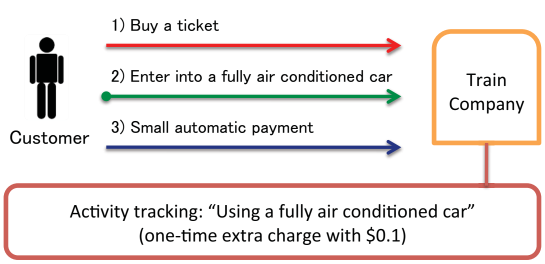

Figure 4. Transaction flow of the UbiPayment model

In the UbiPayment model, the initial cost of a service would be smaller than in the conventional case, because vendors can expect additional revenues from the micro-payments. It also has certain benefits to consumers: they obtain the possibility of leaving out unnecessary options (i.e., actions) that are normally bundled into the price of the service, reducing costs. The UbiPayment model comes from an earlier study we conducted on the possibilities of ubiquitous payments, explained below.

UbiPay System

In [8], we developed a prototype of a ubiquitous billing system called UbiPay. UbiPay consists of two components: a mobile device with an accelerometer and a server that offers services. Money can be charged into the device so that consumers can purchase items and services in a mobile payment fashion. The main difference compared to conventional mobile payment systems, such as Suica [5], is the price range of the payments. UbiPay aims at facilitating the billing and payment of services of extremely small value by minimizing the cognitive load of the payment process. For example, in Tokyo, trains have two types of air conditioned cars: fully air conditioned cars and reduced air conditioned cars. The fully air conditioned cars are more comfortable and costly to operate than the reduced air conditioning cars, but the ticket price for both train cars is the same. The action "using a fully air conditioned car" cannot be billed separately at the moment. The UbiPay system breaks this bundle by making it possible for the train operator to charge different fees from commuters according to their choice of carriage.

The unique feature of UbiPay is that the consumer can assign three configurable user interaction modes to be invoked at different price ranges: automatic payment, light confirmation with simple gestures, and authentication with a PIN code. This feature aims at decreasing the transaction costs of the purchasing process. Transaction cost is an economic term that is used to refer to any cost, either in the form of money, time, effort or other disutility, which is incurred in the process of making an economic exchange [13]. In services with a very small single purchase value, payment-related transaction costs can represent a very large fraction of the total cost. It is not feasible to charge on a per-use basis for such services using conventional payment systems (e.g., stored value card, credit card), because the act of payment can incur more effort than the service itself is worth.

In the train car example, when the consumer steps into a fully air conditioned car, UbiPay recognizes the action and withdraws an air conditioning fee from the consumer's mobile device. If the air conditioning fee is in the price range that is associated with the automatic payment mode, billing will be completed immediately and automatically without any distraction to the consumer. The consumer can view the payment history later to see the total amount of money spent on air conditioning in a month, for example.

Concerns with Automatic Payments

In a user evaluation of the UbiPay system, certain technical and psychological problems were identified in implementing it in practice. We performed an experiment to evaluate the usability and acceptability of the system, where 14 participants joined the experiment, most of them students (male: 10, female: 4). We asked them to use the system in a controlled setting and fill in a questionnaire afterwards. Results of the experiment suggested that users feel reluctance towards fully automatic payments.

Firstly, the respondents had concerns regarding unnoticed manipulation and fraud. To the question "How did you feel about letting the system conduct automatic payments without your awareness?", five participants responded "I felt reluctant" and eight participants answered "I felt slightly reluctant". This was due to the potential of incorrect payments, such as the vendor making a mistake, the consumer misunderstanding the pricing method or someone attempting to commit a fraud. In the prototype, the consumer could accidentally pay other's bills, increasing distrust.

Secondly, it was difficult for the vendor system to recognize consumers' activities correctly. In order to achieve fully automatic payments, wireless communication must be used between the handheld device and the vending machine. Even though many wireless communication technologies (e.g., Bluetooth, wireless LAN, ZigBee) are available, none of them can eliminate the potential for incorrect payments. For example, if multiple handheld devices are detected in the vending machine's communication range, it is difficult to identify who is actually purchasing the items. Therefore, new techniques for identifying the consumer are needed in achieving automatic payments.

We created the light confirmation mode to reduce the occurrence of incorrect payments, but it introduced certain new issues. In the light confirmation mode, the consumer had to make gestures with the handheld device, such as tapping it twice, in order to approve a payment request. However, the recognition system had a less than perfect recognition rate, meaning that it could be quite difficult to use, sometimes even increasing instead of reducing users' cognitive load.

As is apparent from the above, it is challenging to realize an automatic or semi-automatic payment system that will be perceived as sufficiently safe and secure by consumers. We therefore decided to experiment with a different approach, reversing the transaction flow and thus placing the semblance of risk on the vendor's side.

UbiRebate Model

As pointed out in the previous section, the psychological reluctance is an important issue in payment systems. We therefore considered how the payment system can reduce this reluctance without changing the total volume of transactions. As shown in Figure 5, the UbiRebate model returns some amount of money back to the consumer according to the consumer's actions.

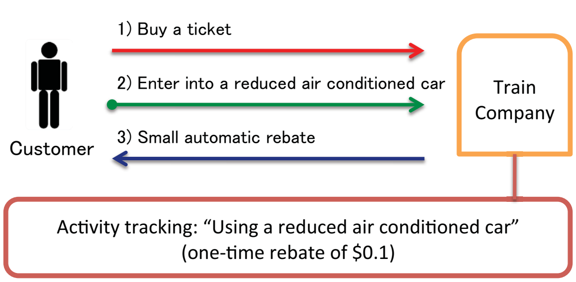

Figure 5. Transaction flow of the UbiRebate model

The concern over incorrect payments or system errors comes from "paying" without awareness, as in skimming of smart cards. There are three possible approaches to solving this issue. One is adding a confirmation phase after the transaction completes. Another possibility is a tracking back feature that allows a consumer to decline incorrect transactions. It is too difficult to implement this feature, however, since purchasing items in the activity-based billing system are consumers' activities, not physical objects. In traditional payment cases, incorrect transactions can be tracked back by returning the item. It is not possible to track back consumers' activities, however, so payments cannot be easily refunded. Moreover, proving the invalidity of activity-based billing is also difficult, since human bodies are always in a transitional state. Therefore, it is unrealistic and prohibitively costly to validate system errors for every claim.

The third approach is eliminating the "paying" process from the automatic payment system. In this approach, the initial payment is set higher than in the previous example, but rebates are paid for particular activities instead of additional payments. The concept of this approach comes from psychological aspects of consumption behavior. In general, people resist paying from their wallet, but want to "get" something instead [9]. The UbiRebate model automatically gives micro-rebates that replace the automatic payments for opposite actions. The UbiRebate model enables vendors to implement an automatic billing system that overcomes the consumer reluctance issue. Contrary to the automatic payment case, consumers may feel happy when they get a rebate for their actions, even though the total economic impact would be the same. Also, there is no satiation in the pay-as-you-do model, but the amount of maximum payment is ensured in the rebate-as-you-do model.

As with the first model, UbiRebate should inform the consumer on how what kind of behaviors will lead to rebates. Then, after the transaction is completed, the system shows the results to consumers. However, the confirmation phase is not important in the case of UbiRebate, because the onus of ensuring the correctness of payments is shifted on the vendor. Rebates that the consumer feels entitled to but does not receive should create less problems than incorrect payments. Also, instead of real money, a virtual currency such as airline miles or loyalty program points could be used in the rebate transactions. This would further alleviate the reliability problem.

UbiReward Model

The third model is UbiReward, which removes the initial payment process from the UbiRebate model (Figure 6). Unlike in the UbiPayment and UbiRebate models, consumers do not pay any fees for service use. Vendors indirectly obtain revenues from the consumers' actions, which are motivated by direct economic incentives. Such actions can include watching advertisements, filling out surveys, doing actual productive work, or saving energy.

A practical use case for the UbiReward model is a power saving scenario in an office environment. As many companies encourage employees to save energy, reducing unnecessary power consumption helps cutting costs. The UbiReward could be used to encourage employees and customers alike to take actions that save energy.

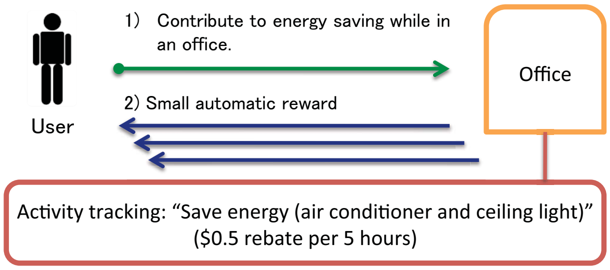

Figure 6. Transaction flow of the UbiReward model

An employee has a mobile device and small sensors embedded into the office environment, so that light conditions and temperature can be sensed. The user can get a micro-reward under the following conditions:

1. Air conditioners: the user does not use air conditioners with unnecessarily high power for one hour. Needlessness is defined by the difference between inside and outside temperatures.

2. Ceiling light: the user does not use ceiling lights unnecessarily while enough sun light comes from the outside. Needlessness is defined by the difference between inside and outside light conditions.

The location of the employee's seat and other factors that affect the conditions (e.g., layout of the partitions, structure of the office room) are taken into account in the pricing policy. With wireless networking, the billing system establishes a connection to the user's device and starts analyzing context information in the area when the person enters an office room.

UbiTrade Model

The UbiTrade mode involves multiple participating consumers. One of the three models explained above is used as a basis, but the pricing of the activities reflects other participant's behavior and interests. This can be realized through a marketplace where buy and sell offers on actions combine to form market prices. Figure 7 shows a transaction flow of the UbiTrade model.

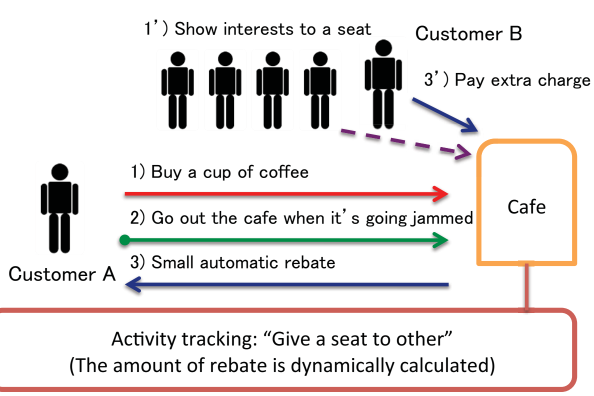

Figure 7. Transaction flow of the UbiTrade model

With the UbiTrade model, the price of consumer actions is dynamically calculated in a way similar to a stock price. For example, in a cafe, the value of a seat changes according to the occupancy rate of total seats. At busy times, the value of occupied seats becomes higher than at normal times. If a customer is sitting on one of the seats, they have two options: either continue using the seat, or give the seat to another customer. Usually, the people who are waiting for vacant seats cannot explicitly encourage the occupants to leave the cafe. With the UbiRebate model, however, the waiting people can price the customer's voluntary action (i.e., giving away the seat) and inform the occupant of this incentive in an explicit way. The occupant can make the decision according to the amount of money at stake; whether it is worth taking the action. If the occupant decides to leave the cafe, a rebate is given to them and charged from the bidder who was waiting for the seat. Both direct and indirect negotiations among customers are conceivable. Direct communication might not be comfortable for some customers, however, so the cafe should mediate the communications in one way for the other.

In a UbiPay-based scenario, users could make offers on how much they are willing to pay to the cafe for the seats, meaning that the seat under you may become increasingly expensive to you as more people bid for it.

EVALUATION

In the above sections, we explained four basic models of activity-based micro-pricing. In order to evaluate the feasibility of these concepts, we performed two experimental studies. The research questions shown below were explored using two corresponding prototype applications.

RQ1: How strongly does the difference between incentive models affect consumer behavior?

RQ2: What is the social acceptability of activity-based micro-pricing systems?

In the sections below, we describe the methods, implementation and results of the evaluation.

Economic Incentives and Behavior Alteration

Method

In this study, we developed a flash application to perform an experimental study on the RQ1. This application gives the task to a participant, which requires continuous actions in a short period of time. Figure 8 shows a screenshot of the application.

In the application window, two boxes are shown in the right and left side. 100 circle objects appear when the examination starts, and the participant is instructed to drag-and-drop the circles from the left box to the right one. The counter in the right box shows how many circles were transferred by the participant, and the time gauge shown below the window indicates how long time remains. 60 seconds were given for each round, and the participant had to transfer as many circles as possible. Also there is another way to transfer the circle objects. When the participant turns on the button left

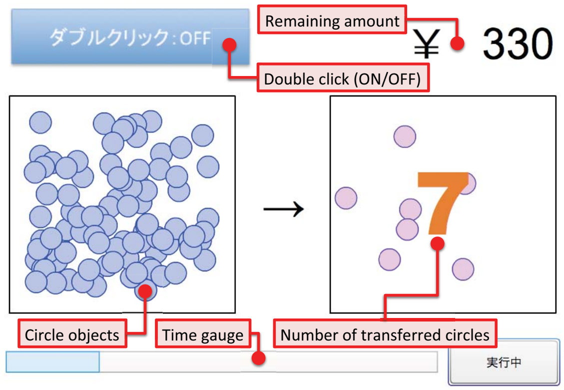

Figure 8. A screenshot of the flash application

above, a special tool is enabled and the circles can be automatically transferred by double-clicking them. Using this tool is much easier than dragging the circles, but economic penalties are given per certain amount of time.

In this study, we prepared two application scenarios that correspond to UbiPayment and UbiRebate model, in order to evaluate the difference of incentive models. At the beginning of each round, 500 JPY [1] is given to a participant. Also in addition to this base point, bonus points are given at the end of test. The bonus point is calculated from the number of transferred circles. Then, the participant starts the task with below conditions according to the scenario:

UbiPayment: No initial cost has to be paid, but 5 JPY is withdrawn per 2 seconds when the tool is enabled.

UbiRebate: 200 JPY is withdrawn at the beginning as an initial cost, but 5 JPY is rebated per 2 seconds when the tool is NOT enabled.

In order to avoid making strategies and to observe psychological effects, only 1 round test was conducted for each scenario per 1 participant. Before starting the tests, a practice phase was allowed to get used to manipulate circle objects with a laptop PC's touchpad. 12 university students joined this test as participants (male: 11, female:1, age: 22-25), and some questions were asked after finishing the test.

Results

Table 1 shows the experimental result of the flash application test. Total number of transferred circles (a), the remaining amount of points (b), and time taken to use the tool (c) were recorded with checking whether the tool is used or not. As shown in the table, the number of transferred circles were almost same between the UbiPayment and UbiRebate scenarios. However, as (c) indicates, participants tended to use the tool longer time in the UbiRebate model than the UbiPayment model. It means that the UbiRebate model could strongly encourage the participants to use the tool, even though a bigger amount of initial cost was withdrawn.

[1] 1 USD $\simeq$ 98.84 JPY as of 15th April 2009

	UbiPayment	UbiRebate
(a) Transferred circles (num)	60.91	61.33
- Dragged circles (num)	36.58	31.75
- Double-clicked circles (num)	24.33	29.58
(b) Total point (JPY)	762.08	702.5
- Base point (JPY)	457.50	395.83
- Bonus point (JPY)	304.58	306.66
(c) Time taken to use the tool (sec)	17.00	38.33

Table 1. Averaged experimental result of the flash application test. (bonus point = 5 * the number of transferred circles)

We also asked several questions to the participants, in order to investigate how they feel the difference of the models in the experiment. Some of the participants commented that they felt anxious or sad when using the tool in the UbiPayment scenario, because their money was lost. As we explained above, the loss aversion worked and it prevented them from using the tool. On the contrary, the rebate made the participants elevated. The UbiRebate model also led to use the tool, because no risk for losing money was concerned in the decision.

Acceptability of the Micro-Pricing World

Method

As a second study, we set up an experimental environment in our laboratory. This study corresponds to the RQ2, and we wanted to evaluate how consumers feel about the concept of activity-based pricing in real settings. The experimental environment was presented as a Japanese-style comic cafe (*manga kissa*), and several kinds of services were installed as shown in Figure 9. For example, participants could play a game (Nintendo Wii), read comics, browse web sites, and use a toy gadget (Chumby). A display installed on the wall shows a list of possible actions where participants can check which actions are priced and how much they cost. A prototype of the billing system was developed for this study.

A mobile device (iPod Touch) was handed to participants before the study started. 1,000 JPY was virtually charged into the device and participants could freely enjoy the services using the money. The remaining amount is displayed on the mobile device (Figure 9), and the participant can configure feedback settings by flipping the window. Under default settings, the mobile device periodically checks whether any transactions have been conducted or not with a 10 second interval. If remaining amount is changed, sound notification is given to the participant. The participant can change the feedback interval and enable/disable the sound notification. This feature was implemented to provide insights into appropriate feedback design.

In the same as with the first study, we prepared two scenarios: UbiPayment and UbiRebate. Table 2 shows priced actions and corresponding price in the UbiPayment scenario. Also Table 3 shows the action list in the UbiRebate scenario. For example, in the UbiPayment scenario, a participant has to pay 100 JPY at the beginning. Then, if the participant plays a Wii game, 10 JPY will be automatically withdrawn from their mobile device per minute. In contrast, in the UbiRebate scenario, the participant has to pay a big-

Figure 9. A comic cafe setup and a mobile device user interface for the experimental study

ID	Action	Interval	Payment
A0	Initial cost	-	100 JPY
A1	Play Wii	1 min	10 JPY
A2	Read a comic	1 min	5 JPY
A3	Turn on a light	1 min	1 JPY
A4	Have a snack	(per 1 snack)	10 JPY
A5	Play Chumby	1 min	5 JPY
A6	Browse web sites	1 min	5 JPY

Table 2. Action list in the UbiPay scenario

ID	Action	Interval	Rebate
A0	Initial cost	-	500 JPY
A1	NOT play Wii	1 min	10 JPY
A2	NOT read comics	1 min	5 JPY
A3	NOT turn on a light	1 min	1 JPY
A4	Have a snack	-	- JPY
A5	NOT play Chumby	1 min	5 JPY
A6	NOT browse web sites	1 min	5 JPY

Table 3. Action list in the UbiRebate scenario

ger initial cost than in the UbiPayment scenario (500 JPY). However, if the participant does *not* use services, the corresponding amount of money is automatically rebated to their mobile device. For example, if they play a Wii game, the sum of all the actions' prices excluding A1 is rebated each minute.

Participants were instructed to stay in the room for 10 minutes for each scenario. While the study was performed, we monitored the room with a web camera and used the Wizard-of-Oz technique instead of using the context recognition module explained in Figure 3. In the monitor's display, a check list is shown and performed actions can be checked accordingly. Then the amount of payment/rebate is automatically calculated, and the remaining amount is updated on the mobile device's display. Six university students joined this study as participants (male: 5, female:1, age: 22-25). We recorded how they configured the feedback settings in the experiment. We also asked several questions about their impressions regarding activity-based micro-pricing at the end of the test.

	Question	Point
Q1	What do you think about the duration of the test? (5: too long - 0: too short)	2.5
Q2	What do you think about the size of the payments in the UbiPayment scenario? (5: too expensive - 0: too inexpensive)	3.0
Q3	Did you feel nervous or anxious in the UbiPayment scenario? (5: strongly felt - 0: did not feel)	3.1
Q4	What do you think about the size of the rebates in the UbiRebate scenario? (5: too big - 0: too small)	3.0
Q5	Did you feel happy or satisfied in the UbiRebate scenario? (5: strongly felt - 0: did not feel)	3.3

Table 4. Questions presented to the participants and the mean responses (5-point Likert scale)

Results

On average, the participants performed approximately 2.5 different types of actions in the UbiPayment scenario, and 2 kinds of actions in the UbiRebate scenario. As shown in Table 4, they felt that the test duration was not long (Q1), and the price of payments/rebates was neither expensive nor inexpensive (Q2 and Q4). The responses to Q3 and Q5 suggest that each model affected to the participants' mental state: they felt anxiety over UbiPayment model, and satisfaction in the UbiRebate model. However, some of the participants pointed out that camera monitoring was one reason for their anxiety, so we cannot assert that loss-aversion effects in the UbiPayment model are the only explanation for the responses to Q3.

In the experiments, only two participants customized the time interval of the sound notification. In the questionnaire, they commented that frequent sound interruption was annoying. One of the participant felt that even rebating becomes annoying due to frequent notification. Alternative ideas in their comments are notifications with vibration, notifications without sound, and notification with price limitation. Almost of all participants preferred to decrease notification frequency, and 7.2 minutes was the average interval that they would set if the activity-based micro-pricing got realized. Also some of the participants commented that simple authentication or confirmation is needed in the payment transactions, but it is not necessary in the rebating transactions.

DISCUSSION AND FUTURE WORK

In this paper, we have introduced the concept of activity-based micro-pricing. Even though the concept has potential for new business opportunities and resource conservation, the cost of manual activity recognition prevents its commercial adoption. Therefore, we proposed to apply ubiquitous computing technologies to implement effective activity recognition, and introduced our idea to bill consumers' activities in a wide variety of situations. In our vision, vendors can effectively charge for users' activities on a per-action basis. At the same time, wider choice is provided to the consumer, who can avoid unnecessary costs that are normally bundled in the price of various services. In order to bring the concept into a concrete shape, we introduced four different models. User evaluation suggests that the choice of incentive model affects consumers' behavior and has an impact on the social acceptability of the activity-based micro-pricing.

In this section, we discuss in more detail some insights and challenges identified in the experiments, consider possibilities for future work, and reflect on related work in incentive design and persuasive computing.

The Gap between Experiments and Reality

Since we performed experiments in a controlled laboratory setting, there could be gaps between the experiments and real world outcomes. Firstly, actual money owned by the participants was not used in the experiments. Even though we could observe how the model differences affect consumers' decision making, results could be different due to, for instance, the endowment effect[2]. We believe that the trend of consumers' decision making does not drastically change, but it is difficult to confirm in a laboratory controlled experiment, because services in the space have to be attractive enough for participants to stay for a while and also enough valuable to voluntary pay their own money.

In the experiments we also used the Wizard-of-Oz technique to conduct payments/rebates, instead of sensor-based automatic activity recognition. The activities that interact with digital devices (e.g., play Wii, turn on a light) are easy to detect, if we can access and retrieve the internal state of corresponding service or device. Thus it is possible to set the transaction interval with fine granularity (e.g., an international call is charged on a minute basis). The payment scheme becomes understandable and clear to consumers, since transactions are conducted while they are actually using the service. Through direct interaction with devices, consumers can obtain a clear picture of the system's behavior.

On the other hand, activities that relate to interactions with non-digital objects are difficult to track (e.g., reading a comic, having a snack). Even though it might be possible to capture the user's motion with visual analysis (e.g., book reading), installation cost would increase because multiple cameras are needed for robust detection. Moreover, the definition of activity becomes vague, since it cannot be digitally judged. For example, from the consumers' viewpoint, the definition of "reading a comic" might be literally reading a comic, not simply holding a book or placing a book on the desk. We can monitor a bookshelf with RFID tags and charge a fee while a comic is being taken out, but the consumer might not expect to pay while they are not actually reading the book. The passive observation tends to hide the whole system behavior from consumers, but system errors and limitations should be disclosed in a human-readable way. Otherwise there could be the serious gap between the payment scheme and a consumer's understandings (i.e., mental model about the system behavior). Thus the volume of inference logic should be minimized in a context analysis process.

The technology limitations directly relate to economic risks, because cheats could be possible if a complex activity detection process becomes automated. Therefore it is important to consider how manual monitoring can be supported by technologies, instead of trying to automate the whole billing process. The selection of system model is also important to decrease the economic risk. As we mentioned the impact of incorrect rebate is smaller than incorrect payment, so UbiRebate model is more appropriate when the recognition accuracy is not high. In other words, the context recognition module can be simplified in UbiRebate model and it results in cost saving. With UbiPayment model, vendors can expect additional gains, but consumers' activities have to be checked with enough accuracy. As a result, system installation cost and labor costs would increase, because man-powered checks are required as well as special installations for context recognition.

Lightweight interaction

In the experiments, the automatic confirmation mode was applied and we did not allow the participants to deny activity-based billing. However, as we pointed out in [8], lightweight interaction design is an important issue if the billing system presented in this paper is to be implemented in practice. Interactions in the system take place in two directions: feedbacks from the system to the consumer, and confirmation responses from the consumer to the system. In the activity-based billing system, transactions can occur very frequently, so notifications should be delivered with consideration to their level of importance. One of the participants commented that they felt happy getting rebates, but that the frequent notifications somewhat detracted from this feeling. One possible solution is to implement a threshold-based notification system: the mobile device alerts when the total amount of payments reaches a previously configured threshold. This decreases the frequency of interruptions and cognitive workload for handling the information. Changing the billing mechanism can also contribute to a decrease in the number of interruptions. The UbiRebate or UbiReward models do not need to notify the remaining amount at every update, so the consumer might prefer to manually check the amount by themselves.

Related to the feedback design, lightweight confirmation is also important. Completely automatic processing makes consumers anxious and leads to reluctance towards adopting the service. However, heavy-weight confirmation such as the conventional PIN code is not suitable for handling frequent transactions. It is necessary to select an appropriate confirmation style according to the risk level of the transaction. In [8], we enabled the use of multiple confirmation styles to adapt to a wide range of purchase amounts. However, it is also important to consider the transaction flow in each billing model. For example, in the UbiRebate model, the initial cost is big and all transactions after the first payment give rebates. Thus it will be fine to apply secure PIN code -based confirmation at first, and change to automatic processing for the subsequent rebates.

Incentive Design for Sustainable Behavior Impact

Consumers' decision making is strongly influenced by economic incentives, but in this study we noticed several challenges in this approach. For example, too much mental pressure makes services uncomfortable to use. Also, requiring too much attention prevents consumers from enjoying the

[2] A hypothesis according to which people place a higher value on objects that they own than on objects that they do not.

service. One alternative approach is to apply social psychological incentives that try to effect behavioral changes by appealing to consumers' values and ethics. Social incentives are especially effective for tightly linked communities (e.g., families). For example, Nakajima *et al*. proposed an "ambient lifestyle feedback system" to effect changes in our daily behavior [12]. In their work, several kinds of pervasive applications were designed while considering emotional engagement. For example, if a child does not brush their teeth in the correct manner and frequency, a virtually presented aquarium becomes dirty and its virtual fish fall sick. The virtual aquarium is installed in a bathroom, so pleasant and unpleasant feelings evoked by the application are shared among family members. Thus social pressure provides motivation for each individual to keep the aquarium clean through proper tooth brushing behavior.

Social incentives are also expected to compensate for technical limitations. Shiraishi *et al*. developed an application called *EcoIsland*, which is a system persuading individuals to reduce CO_2 emissions [15]. In their work, economic incentives are implemented as EcoPoints, a virtual currency used in EcoIsland. Users can earn EcoPoints by reporting eco-friendly actions they have achieved, and the points can be used to purchase items to decorate their virtual island in a way that visualizes each family's contributions to CO_2 reduction. In the application window, users can see other families' islands so that they can compete and improve their behavior in a playful fashion. Moreover, this social networking feature decreases dishonest behavior that is otherwise possible due to technical limitations. Since eco-friendly actions are often too complex to detect automatically, it is hard to verify users' self-reported data. The social aspect of EcoIsland allows users to monitor each other, providing peer pressure against cheating.

A hybrid incentive approach could cover a wider range of users within an application. Each individual has their own preferences, and multiple types of incentives increase the chances of them developing interest in the application. Moreover, social psychological incentives work most effectively inside groups or communities, while economic incentives operate on the individual consumer level. In a local community, users know each other and they collaborate to maximize their total benefit, instead of taking actions that are detrimental to each other. To avoid the tragedy of the commons, it is important to try to bring together a small community and offer a virtual space (e.g., islands in EcoIsland) to smoothen its communication and collaboration.

Finally, it is recognized that once a user is motivated by economic value, previously existing social incentives become inoperative, even after the economic incentive is removed [2]. Thus we should be careful in designing the balance between social psychological incentives and economic incentives. Social psychological incentives are powerful and work sustainably in a smaller community, so economic incentives should not be introduced until necessary. In contrast, for bigger groups in which anonymized users are loosely coupled, economic incentives probably work better. This is because users start to make their decisions individually, and economic values become prioritized over other kinds of values. The activity-based micro-incentive approach presented in this paper should thus be especially suitable for places and situations involving large numbers of general public.

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