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Watch your Emissions: Persuasive Strategies and Choice Architecture for Sustainable Decisions in Urban Mobility

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ABSTRACT

Persuasive technologies are suitable for encouraging green transportation behaviour towards CO_2 emissions reduction. For example, such technologies can guide and support users in finding trips that cause low emissions and in the long term change their behaviour and habits towards more sustainable transport decisions. In this paper, we focus on persuasive strategies supported by a choice architecture approach and incorporated in a smartphone application, aiming at providing urban travellers with a solution that will influence them to consider the environmental friendliness of travel modes while planning a route. We focus specifically on the persuasive strategies of Reduction, Tailoring, Tunnelling, Cause-and-Effect Simulation and Suggestion. The choice architecture approach leverages routing options and results of a commercial routing engine in order to provide proper default options as well as filter and structure the results according to user preferences and contexts while emphasizing environmentally friendly routes. Our approach is integrated in a route-planning assistant for everyday use that is implemented for Android mobile phones and follows a client–server architecture. An evaluation with 24 participants using the system for 8 weeks showed good acceptance of our approach, increased environmental impact awareness, and qualitative comments also conveyed instances of behavioural change.

Keywords: *persuasive strategies and technologies, choice architecture, CO2 emission reduction, urban mobility.*

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1. Introduction

In urban areas transportation is a constant and important factor of growth and employment, but also a major source of carbon emissions (Cofaru, 2011). The problem of increasing emissions can be addressed on one hand by means of improved infrastructure (e.g., adequate and environmentally friendly public transportation options) and urban design, and on the other hand by increasing travellers' awareness of the environmental impact of travel mode choices. In this context, persuasive technologies, tailored for and integrated in route planning applications, can affect urban travellers' decisions and guide them towards selecting routes that are environmentally friendly.

Persuasive technologies may use a large number of strategies to induce behavioural change (Fogg, 2002; Cialdini, 2001; Torning and Oinas-Kukkonen, 2009). Implementations can take various forms, including the design of visual feedback systems or systems that guide users by properly structuring the available choices in decision making situations (Fogg, 2002). Choice architecture (Thaler, Sunstein and Balz, 2010) refers to designing and incorporating small features or nudges in the decision making process in order to highlight 'better' alternatives for the users and assist them in choosing a desired option, while not restricting their freedom of choice. In our case, 'better' alternatives refer to more sustainable transportation options. Ideally, individuals who use mostly their car start using public transportation, while those who already use public transportation or cycle sustain their current habits or increase their use of bicycles.

Due to the complexity of a metropolitan transportation network, finding and selecting efficient and sustainable transportation options is not a trivial task. In order to support this task, routing systems have been introduced that provide information on environmental factors associated with a route, e.g. the expected CO_2 emissions for a given route (In-Time, 2014; Reitberger, Ploderer, Obermair and Tscheligi, 2007). Such systems are designed to help users in making informed choices. However, they do not fully capitalize the possibilities of detailed route related information (e.g. regarding emissions) for influencing the users' trip choices.

In this paper, we propose a set of persuasive strategies for route planning applications. These strategies, namely Reduction, Tailoring, Tunnelling, Cause-and-Effect Simulation and Suggestion, are deployed both in the visual user interface and in the design of an underlying choice architecture system. The system filters and ranks the available trip choices by considering user preferences and contextual elements while trying to balance user-related parameters such as perceived route utility (e.g., trip duration, usability), comfort and CO_2 emissions. The remainder of the paper is structured as follows: Section 2 provides an overview of the related work and describes the concepts of persuasive technologies and choice architecture. Section 3 provides an overview of our approach whereas Section 4 describes the architecture of our system and the implementation choices. Section 5 presents the results of our trial and discusses the implications and limitations of our approach. We conclude in Section 6 with our final remarks and directions for future research.

2. Background and Related Work

The work presented in this paper is influenced and informed by two areas of research, namely persuasive technology and choice architecture. This allows us to view the problem of sustainable travel behaviour from different scientific perspectives and traditions.

2.1 Persuasive Technology

Ever since Fogg's (2002) popularization of persuasive technologies, persuasion has been utilized in different application domains such as health, environmental awareness and education (see Wiafe and Nakata, 2012; Kimura and Nakajima, 2011). In all these domains, users of persuasive technology are guided towards the adoption of desired attitudes or actions. Ecologically sustainable behaviour has been of particular interest to system designers (DiSalvo, Sengers and Brynjarsdóttir, 2010; Froehlich, Findlater and Landay, 2010). Such systems typically employ a number of persuasive strategies, such as those suggested by Fogg (2002) and others (Torning and Oinas-Kukkonen, 2009), to motivate users to choose a more environmentally behaviour.

A number of studies have dealt with promoting environmentally friendly modes of transportation, such as public transportation, cycling or walking. This is usually done through mobility tracking combined with CO_2 feedback (e.g., UbiGreen (Froehlich et al. 2009), CO2GO (MIT, 2014)). While these systems are limited to give feedback on past behaviour, the SuperHub system (Gabrielli and Maimone, 2013) supports the user in choosing a sustainable transportation by estimating emissions prior of actually performing a trip. Although these existing approaches allow multimodal routing and include some form of pre-trip CO_2 emission information, they simply include it in the application or website, but do not actively nudge users with persuasive strategies towards a desired choice.

In order to overcome this limitation, the central element of our approach is the consideration of the following five persuasive strategies in the routing process: The first strategy employed is Reduction, which refers to making a complex problem as simple as possible and giving only a few simple but meaningful alternatives to the user. Most of the complexity of the routing system is moved into the background, where it is not visible to the user. The second strategy, Tailoring, ensures that only personally relevant information is presented to the user. By this, much more background information (e.g., on possible CO_2 emissions) can be taken into account and, at the same time, information overload for the user is avoided. The third strategy is Tunnelling. This means that the application should point the user in the desired direction, in our case towards an eco-friendly route choice. The forth strategy is Cause-and-Effect Simulation, which influences users to immediately observe the link between cause and effect by making them aware of the consequences of their potential future actions. The final strategy used, Suggestion, means that the persuasive technology should properly communicate a recommended choice at the most appropriate moment.

2.2 Choice Architecture

The concept of choice architecture can be facilitated to implement the persuasive strategies mentioned above. Effective choice architecture is based on a set of principles, which, when applied carefully, can guide human decision-making (Thaler et al., 2010). In our work we focus on: Defaults, which refers to preconfigured options people receive if they do not explicitly request something different and usually make use of due to laziness, fear, or distraction; Structuring Complex Choices, which is about helping users to identify alternatives that correspond to their preferences; and Choice Overload, which is related to the limited cognitive capacity of individuals that does not allow to consider every available option.

The effects of defaults have been shown on a variety of real-world decisions in domains such as investment, organ donation, marketing, and beyond (Goldstein, Johnson, Herrmann and Heitmann, 2008). Defaults can take a number of forms including simple defaults (choosing one default for all) and forced choice defaults (forcing the user to make an active choice before delivering a product or service; Wilson, Garrod and Munro, 2013). The structure of the choice set has implications on the exploration of the alternatives, such as the information and attributes examined but ignored (Levav and Iyengar, 2010). Commonly, individuals first screen alternatives on a subset of attributes and then include the remaining attributes. However, the small set of attributes compared first can receive stronger preference (Diehl, Kornish and Lynch, 2003). Choice overload is the state when users are overwhelmed with alternatives (Johnson et al., 2012). Although there is no real recommendation in the literature how many alternatives should be present without overloading users, findings indicate that a selected number of choices should encourage a reasoned consideration of trade-offs among conflicting values and yet not overwhelm the user (Johnson et al., 2012). Moreover, a limited array of six choices was found to increase subsequent satisfaction with the choice made compared to an array of 24 or 30 choices (Iyengar and Lepper, 2000).

Studies of choice architecture in transportation have focused on the presentation of travel related information and related effects on transport mode choices. Avineri (2012) presents a set of concepts that are inspired by recent developments in behavioural economics and cognitive psychology, and describes their application to the next generation of travel information systems. Namely, he discusses the use of defaults, gain/loss framing and social influences. The strong influence defaults have on behaviour can be used to promote certain behaviours, depending on how the defaults are set. Another strong influence on behaviour is the presentation (or framing) of information in terms of gains and losses. People are more sensitive to losses and seek to avoid them more than they seek gains (“loss aversion”). Therefore, information about a desired behaviour should be framed accordingly. Yet another potent impact on behaviour stems from the presence of others. People tend to change their individual behaviour in the presence of others and are encouraged to continue to do things when they know that others approve of their behaviour (Avineri, 2009). Our work implements parts of this vision.

3. Our Approach for Sustainable Decisions in Urban Mobility

Route planning applications allow users to find ways to reach a destination. The most common process is to enter a start and destination address or point in a map and then a routing engine calculates alternative routes to reach the destination. Recent developments guided by advances in routing algorithms and availability of alternative transportation means have resulted in the development of multi-modal route planners. The concept of these multi-modal route planners is to calculate trips that involve the use of more than one mode of transportation, such as metro and bus, as well as any combinations of car, bicycle, walking and public transportation. Common terms used for these combinations are ‘park and ride’, which refers to taking the car to a parking spot and then continuing with public transportation and ‘bike and ride’, which refers to using the bicycle to reach public transportation means and then either parking the bicycle or taking it along.

Moreover, route-planning applications offer a number of options that allow fine-tuning the calculation of the trip results as well as filtering them (see e.g., the online application offered by the Vienna Region in Austria: http://www.anachb.at/). Fine-tuning options may refer to the type of trips (e.g., shortest, most comfortable), the desired number of changes between transportation means, or the level of road inclination (when walking or cycling is involved). All these options affect sustainable transportation behaviour. Human decisions are, however, usually not optimal because of bounded rationality, which refers to the notion that humans cannot always evaluate all available alternatives due to cognitive limitations and the finite amount of time they have to make a decision (Cremonesi, Donatacci, Garzotto and Turrin, 2012). This results in decisions based on simplistic decision-making strategies, such as heuristics and rules of thumb. These solutions ease the cognitive load of finding a satisfying, but not necessarily optimal, solution.

In our approach we leverage persuasive strategies and use aspects of choice architecture in order to nudge users towards eco-friendly travelling decisions (see Table 1). More specifically, the user interface is designed to offer proper motivation for selecting sustainable transportation options, while the information and choices shown to users are calculated using the principles of choice architecture.

Persuasive Strategies	**Key Choice Architecture and Interface Implementation elements**
Reduction	Condensed complex route options into three simple alternatives. Filtered trips in order to present a few meaningful alternatives.
Tailoring	Balanced trip results based on user preferences and CO_2 emissions thereby avoiding choice overload.
Tunnelling	Users are guided through the route search with a bias towards eco-friendly routes based on the power of defaults: - users are not required to decide on specific modes of transportation in the search process - environmentally friendly options are included by default.
Cause-and-Effect Simulation	Display of estimated CO_2 emissions per alternative trip
Suggestion	Grouped trips per mode of transportation thereby structuring the choice set. The environmentally friendly options are displayed in a more prominent position in the interface.

Table 1: Persuasive strategies and our approach.

Reduction is designed such that the decisions of which route options to set and which transport mode to choose are both reduced to a few meaningful alternatives. If we consider Reduction in combination with Tailoring, the presented trips should be in accordance with the individual's travel preferences. The problem is handled as choice overload and can be described as follows: given a user u, we want to find a subset S of AvailableTrips(u) such that |S| = PresentedTrips and the choice of S provides a good balance between the user's perceived trip utility and his or her CO_2 emissions. Our approach is based on the calculation of trip utility that leverages users preferences provided via the route-planning interface. These preferences are then transformed into a user's perceived trip utility value. The utility and the CO_2 emissions of a trip are provided as input to an algorithm (see Section 4.2 for a detailed description) that selects |S| trips to be presented to the user in a simple and non-cluttered user interface, focusing on the primary task of the user, i.e., getting from A to B.

Tunnelling is handled by a route planning wizard that quickly lets the user search for routes to a specific target destination, while also providing options to set trip preferences. Users are not required to decide on specific modes of transportation in the search process and environmentally friendly modes are included by default. If users omit these modes, we follow a forced choice approach and include results with public transportation, walking, bicycle and park and ride in case these make sense as follows: i) if the destination is in a walking distance we include trips that involve walking, ii) if the user selects public transportation, the option of using a bicycle is also displayed iii) if the user selects the option of car, then the options 'park and ride' and 'public transportation' will be included in the result set as well. The rationale behind this is to show relevant alternatives to those users that might turn off all modes except driving at the very beginning. In these cases, it would not be possible to use persuasive strategies to motivate them to switch to other modes.

Cause-and-Effect Simulation uses CO_2 emissions modelling to calculate the estimated emissions for any given route. For each route displayed in the result set, a corresponding number in grams of CO_2 is shown. The absolute value in contract to a relative scale allows direct comparison of different transportation modes in terms of ratio, making high-polluting options such as the car clearly visible. Thus, the user is informed about the environmental effects before he or she is actually causing them.

Suggestion is performed through the structuring of choices. Our approach is to group the available options in order to allow for optimal comparisons. To this end, we group trips based on one of the major transportation modes, i.e. walk, bicycle, public transportation (this includes ‘bike and ride’) and car (this includes ‘park and ride’). Moreover, in order to nudge users to consider the environmentally friendliest option, the groups are ranked according to CO_2 emissions. In most cases, this leads to a ranking in the following order: walking, cycling, using public transport, and driving.

4. System Architecture and Implementation

Our system architecture is presented in Figure 1. Users interact with our application using a smartphone with the Android operating system. The client-side application incorporates the selected persuasive strategies in a number of screens which are described in Section 4.1. Through the interface users search for routes and browse the calculated route results. The backend application contains the choice architecture logic and is responsible for selecting and adjusting the information displayed to users. The details of our implementation are described in Section 4.2. An external routing engine able to provide uni-modal and multi-modal route results is used to fetch all possible routes towards the destination.

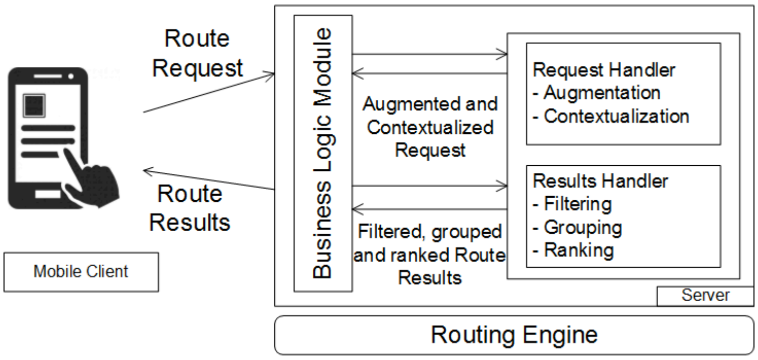

Figure 1: The architecture of our system.

4.1 Persuasive Strategies in the User Interface

The persuasive strategies outlined in Section 3 are the guiding principles of the user interface design. In particular, they are deployed through a number of visual elements. The first strategy, Reduction, was a main driver for a simple and elegant user interface and can be found everywhere in the application. In particular, Reduction is found in the route search screen (see Figure 2.1), which hides away complex search parameters. Additionally, input is reduced to the bare minimum required to be entered by the user, as most input fields are prefilled with defaults (except for trip destination). Tailoring can be achieved if desired, as the user can specify from where, to where, at what speed or comfort level, with which modes of transport, and at what time he or she wants to depart or arrive. By default, all available transport modes are turned on, following the Tunnelling strategy. The user can, however, change individual settings as desired.

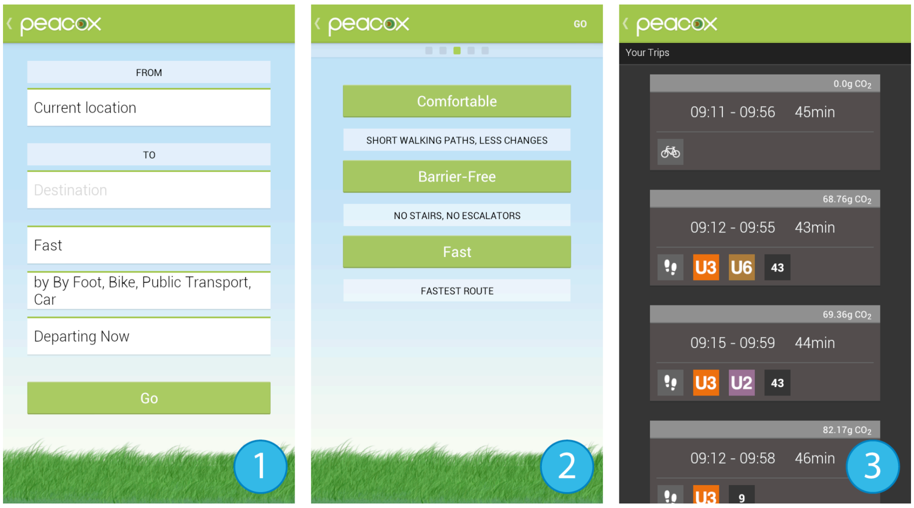

Figure 2: Search wizard (1), trip preferences (2), and route search results (3).

The settings screen (Figure 2.2) is another demonstration of the Reduction strategy. The user is easily able to manually specify preferences in terms of going “fast”, “comfortable”, and “barrier-free”. In the background this is translated to detailed transport mode specific settings, such as “maximum number of transfers” or “maxi-mum walking distance”.

The results screen (Figure 2.3) incorporates all five persuasive strategies. It uses Reduction, as the number of choices presented and the amount of information attached to them is reduced to the most important ones. It shows travel time, modes of transport, and – important for our case – the amount of CO_2 that would be emitted. It uses Tailoring as these results are based on the user preferences. Tunnelling is used on the one hand in the way transportation options are ranked, placing ecologically friendly options higher up. On the other hand, as stated in Section 3, sustainable modes such as walking and cycling will, under certain conditions, be present in the results even if the user explicitly turned them off. Cause-and-Effect Simulation is included through the presentation of CO_2 information for each potential trip. This allows the user to see the (environmental) consequences of their choice prior of making them. Implicitly, the CO_2 information combined with the ranking strategy of placing environmentally friendly options first is an instance of Suggestion, as the application communicates preferred options in this way.

4.2 Choice Architecture in the Backend

The processing in the backend begins when users issue a new route request from the client. The request is sent to the Request Handler that performs contextualization and augmentation. Following this step, the request is sent to the routing engine. The routing results are forwarded to the 'Results Handler' which is responsible for grouping, filtering and ranking the available options with an aim to present the most relevant results, structured and ranked according to CO_2 emissions.

Request Handler. This function first contextualizes the request using weather information retrieved from a publicly accessible weather service. When extreme temperatures or rainy conditions are detected the maximum walking and bicycle time are set to low values below 15 minutes (we consider extreme temperatures < 5°C and > 30°C). Then a request augmentation overrides existing restrictions set by users and always includes walk and public transportation as selected modes of transport. In cases where the car has been selected, the option to include 'park and ride' results is activated. Our aim at this point is to retrieve an increased number of results from the routing engine. At a later stage results that are not relevant are filtered and are not presented to the user.

Results Handler. This function groups filters and ranks the results provided by the routing engine and contains three processing steps. In the first step we group results to four major groups: walk, bicycle, public transportation (this group includes bike take along, bike and ride, public transportation, park and ride) and car. Second, we normalize results and prune those whose total duration and walking/bicycle time exceed certain thresholds under the assumption that lower duration will be preferred by the majority of users. The pruning process begins by identifying the minimum duration, minDur, per group of routes and those which duration exceeds minDur by 1.5 times are omitted. Third, we calculate a utility value per route following the Ordered Weighted Average (OWA) multi-criteria method with the use of the neutral operator (see Rinner and Raubal (2004) for a detailed description of the method). Based on the trips' attributes and characteristics we define four criteria which may take a high, medium and low value as follows:

- *Total route duration*. It refers to the estimated time, which is required to reach the destination for the specific route. The value is given as follows: low for routes with minDur <= routeDuration < meanDur - 0.3*meanDur, medium for when meanDur-0.3*meanDur < routeDuration <= meanDur + 0.3*meanDur and high when meanDur + 0.3*meanDur <= routeDuration, where meanDur is the mean duration per group of routes.

- *Total walking and bicycling time*. This refers to the estimated time that will be consumed in walking and/or cycling for the specific route. The per-route values are calculated with the same manner as in the case of total route duration.
- *Comfort*. It is defined as the number of transportation mode changes within a route. The assumption is that when users need to change a high number of transportation modes, comfort decreases. With this in mind a high value for less than 2 changes, medium for 3 changes and a low for higher than 3 changes.
- *Route emissions*. These are the estimated CO_2 emissions that would be generated if the specific route was followed. To infer the values of this criterion we use the concept of ‘nominal emissions’, i.e. the emissions that would be produced if the route was covered by a means of transportation which produces CO_2 equal to the average metro emissions (estimated at 20 CO_2 grams per km based on transportation authorities’ data). The value is derived by comparing the estimated route emissions with the nominal emissions.

In order to calculate route utilities, following the OWA method, we define a high, medium and low preference level per criterion value. The preference levels are set according to the user selection on the trip type (Fast, Comfortable, Barrier-Free). For example a ‘Fast’ user selection results to a high preference for the low value of the total duration criterion. Finally, each preference level is mapped to a numeric value for later processing: 1 for low, 2 for medium and 3 for high. Once user preferences are identified and all the criteria values are selected, we calculate the total utility per trip as a weighted average of the criteria values and the trip emissions:

$$Utrip = (tD + WB + C)*\alpha + E*(1-\alpha)$$

where tD is the value of the total duration criterion, WB the value of the walking/bicycle duration criterion, C the value of the comfort criterion and E the value of the emissions criterion. We set $\alpha = 0.6$ in order to weigh higher the characteristics of the trip. In order to achieve good coverage with respect to the set of displayed routes while not overwhelm the user with choices, we limit the number of trips to one with walking, one with bicycle, up to three with public transportation, one with car and one with park and ride. This means that the maximum alternatives displayed to the user are seven.

5. Evaluation and Results

In order to study and fine tune our proposed system we ran a trial in the metropolitan area of Vienna, Austria, in summer of 2013. 24 participants used the system on their own smart phones for 8 weeks. Before (t_s), after 4 weeks (t_1) and at the end of the trial (t_2) user feedback was collected by different means. The goal was to assess what impact the persuasive strategies incorporated in the user interface and the choice architecture have on participants.

Participants. We recruited 17 men and 7 women with a mean age of 37.4 years. Their stated main mode of transportation was 54.2% public transport, 25% car, 16.7% cycling, and 4.1% other, which corresponds well with the mode share at the test site. Only cyclists were slightly overrepresented. All users had an Android (Version 4.0 or higher) smartphone with a sufficient data plan that enabled them to execute requests without worrying about data usage.

Procedure. Before the trial an online screening survey (t_s) took place and an introductory workshop was held to familiarize users with the application and its features. Users were instructed to download and install the application on their own phones and perform test requests and change any options they wanted. After the workshop users were instructed to use the application freely without any specific focus for a total duration of 8 weeks. Face-to-face or telephone interviews were held after one week and after 4 weeks of using the application. Additionally, two online surveys were administered after 4 (t_1) and after 8 (t_2) weeks. Users were asked to provide their opinion about the application by answering questions on the usage of the application, their satisfaction with the service, suggestions for improvements, their attitudes towards the environment and different modes of transportation, and their travel behaviour. The users' trips were recorded via their phone's GPS functionality and requests to the routing engine were logged server-side. After approximately a month, a software update was sent out to the users that addressed minor bugs. At the end of the trial, a focus group was held to discuss application usage and behavioural changes.

5.1 Results

Overall, results of the trial were positive. Repeated measures t-Tests were used in order to analyse quantitative data.

Usage Frequency & Patterns. As we expected, the stated frequency of use (M_{t1} = 3.84, M_{t2} = 2.80, 5-point-rating scale ranging from 1 = "no use at all" to 5 = "very often") and the logged number of search requests (see Figure 3) decreased during the course of the trial. This can be explained by the novelty effect, which caused participants to use the application more often in the beginning. The second interviews and the diagram in Figure 3 also show that usage shortly increased again after the software update was issued.

Comparing usage between drivers, public transport users and cyclists, the three user groups differed significantly in their frequency of searching for a specific route ($F = 4.63$, $p = .015$). Cyclists ($M = 3.5$, $SD = 0.96$) and public transport users ($M = 3.5$, $SD = 1.40$) searched significantly more often for specific routes than did car users ($M = 1.83$, $SD = 1.47$).

Most users disregarded the trip settings and accepted the default values. This includes the quick settings “fast”, “comfortable”, and “barrier-free”, as well as the options to turn off individual modes of transport for search (see Figure 4).

User Satisfaction and Usability. Satisfaction with system usability was generally acceptable. We measured overall satisfaction with the application, satisfaction with usability, with structure, and with route suggestions by using single-questions. Satisfaction with usability and with structure remained stable over time. Overall satisfaction increased between the two measurements (from $M_{t1} = 2.68$ to $M_{t2} = 3.08$, 5-point-rating scale ranging from 1 = “very unsatisfied” to 5 = “highly satisfied”), however just failed to reach significance ($p = .057$). The qualitative interviews revealed that the overall satisfaction with the system is largely positive. Users liked the aesthetics of the design of the application. They highlighted its simple interface and non-cluttered functionality. This is an indicator that users framed the application as a tool that supports their primary task of way-finding.

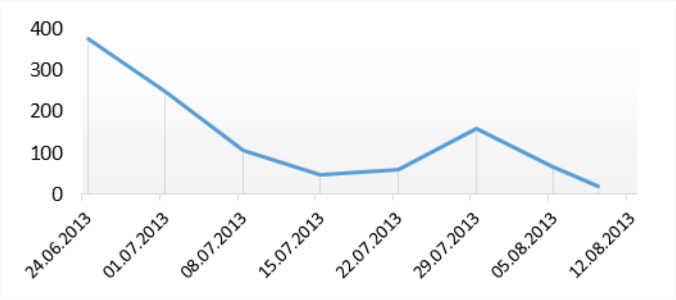

Figure 3: Weekly number of requests. Requests increased after the software update.

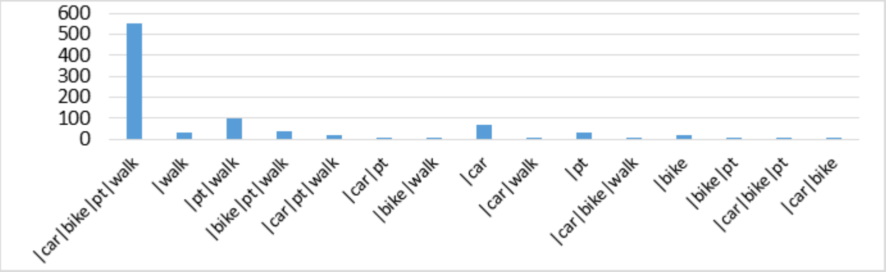

Figure 4: Number of requests per transportation mode setting as selected by the users.

Perception of Route Suggestions. Satisfaction with the route suggestions (5-point-rating scale, 1 = “very unsatisfied” to 5 = “highly satisfied”) was moderate and did increase significantly (from $M_{t1} = 2.76$ to $M_{t2} = 3.2$, $p = .018$), which probably can be attributed to the software update that addressed a search-related bug. During the interviews users stated that many trips they performed during the trial were typical for them, e.g. going from home to work, and they tested the application with these routes. Generally, they were pleased with the results and stated that the suggested alternatives make sense and the routes themselves are realistic. Some users highlighted the positive aspect of being able to compare the different route options on one screen. Through this they realized that, for example, cycling is in many cases not much slower than driving.

As described in Section 3, one persuasive feature was to include walking, cycling and public transport trips under specific circumstances, even when the user had explicitly turned off those modes. However, when such a condition was met the included route was not particularly highlighted or marked in the user interface resulting to questions which led us to explain better the concept to users.

Perception of CO_2 Information. The interviews also covered the CO_2 information associated with the route options presented to the users. The CO_2 information was seen as a relevant part of the route and not as a distracting add-on. They reported an increased awareness in case of unsustainable behaviour, in particular the car drivers. Several of them stated they have a bad conscience when looking at the CO_2 values the application provided for a car trip, which were compared to public transportation usually at ten times higher.

An interesting finding revealed from the interviews and the focus groups is that it was less clear to participants prior to the study that car trips have emission factors about ten times higher than public transport options. While the latter usually ranged in the area of a few hundred grams, driving for a few kilometres quickly pushed the number above a thousand grams. This fact did have a clear impression on participants. Public transport users, cyclists and pedestrians felt confirmed in their choices. Car drivers realised just how big their environmental impact is, or, as one participant put it drastically: “I know now just how much of an ‘environmental pig’ I am.” Despite the very simple representation of CO_2 emissions in the form of a plain number (see Figure 2.3), users made sense of it by comparing the number from one mode of transport with the others.

Attitudes towards transport modes. Attitudes towards transport modes ranged from 1 = “no value at all” to 5 = “high value” and were overall moderately positive. For measurement we adapted the approach proposed by Steg (2005). It consists of three subscales that measure various aspects of attractiveness of a particular mode of transportation. There are instrumental aspects, such as functionality and usefulness, aspects of independence and freedom, as well as affective and symbolic aspects such as prestige and positive attributes, associated with the mode of transportation. The two subscales Instrumental Aspects and Independence did not change over time. The subscale Symbolic and Affective Aspects, however, increased significantly over time for public transport (M_{ts} = 2.44, M_{t1} = 2.57, M_{t2} = 2.79, p = .015, with a large effect of η^2 = .31), meaning that the users rated public transport more positively and prestigious after having used the application for a while.

Attitudes towards the environment. Environmental attitudes were moderately high and stayed stable over time. We measured a significant increase (M_{t1} = 3.23, M_{t2} = 3.51, p = .027, η^2 = .27, 1 = “totally disagree” to 5 = “totally agree”) in locus of control (Fielding & Head, 2011), which is the perceived ability to actually do something positive for the environment. The interviews showed that this could be attributed to the CO_2 information associated with the route options presented to the users. The subscales Environmental Concern (Worsley and Skrzypiec, 1998) and the subscale Sustainable Mobility (Schahn, Damian, Schurig and Füchsle, 2000) revealed no significant changes over time.

Self-reported Behaviour Change. The application could also motivate behavioural changes. While not measurable through the GPS logs, users reported instances of switching from a bus to a tram, as emissions were lower, or following the car route that was more eco-friendly compared to their usual route. However, it needs to be stated that behaviour change was small and limited to short-term effects. This can partly be attributed to the application used being work-in-progress. For example, the potential influence of CO_2 information is underexploited by the current design. There is, however, also the established phenomenon of the attitude-behaviour gap that describes that people do not necessarily act according to their behaviours (Kollmuss and Agyeman, 2002). This gap was confirmed in our case. In the focus groups we identified with the participants that well-established habits (e.g., a person has been a car diver ever since acquiring a driving license) and social conditions (e.g., a person needs the car to bring the children to school) prevent long-term change. We will discuss in Section 6 how to plan to deal with this open issue.

5.2 Discussion

The results of our trial reveal that the choice architecture and the visual representation of it in the user interface were received well in our field evaluation of the system. Our approach provided users with both personally relevant and environmentally friendly options and most importantly avoided discouraging car users from using the application, which is supported by the small number of dropouts and the high satisfaction rates.

The choice architecture approach can be beneficial in the design and implementation of route planning applications aiming to influence users towards selecting environmentally friendly transportation options. As most of the requests were performed using the default settings, it makes sense to set by default options that include walking, the use of bicycle and public transportation. For example, even if a user is predisposed to search for a car route, presenting more environmentally friendly options may provide cues to start considering alternatives or even change her/his plans. Then, by structuring the choice set and presenting first environmentally friendly options while grouping choices by their attributes (e.g. the means of transportation), users can easily identify the environmentally friendly options as well as compare the alternatives and understand the differences on attributes such as travel time and CO_2 emissions. In this manner, users may identify cases where choosing a mode with less emissions makes more sense (e.g. walking to a nearby destination instead of taking the car or switching to public transportation means with lesser emissions). Moreover, as routing engines provide numerous alternatives, a personalized filtering functionality can limit the choice set to a shorter list of options thus reducing the cognitive burden of examining all the available options in the process of identifying the optimal one. The result is that users have the time to make more informed decisions.

As reported the user interface was perceived well by the test participants. However, for future implementations, based on qualitative comments by the users we think it will be helpful to also provide indications to the user on why and how different routes are selected to be included in the initial set of recommendations. Such an improved understanding of the ranking mechanism can help to increase the trust of users towards the presented results, and also can help to overcome a sometimes perceived randomness of suggestions, which should be avoided in order to not confuse the users.

Another design possibility in this context, which we plan to explore in the future, is to provide additional textual information and arguments for selecting a specific proposed route. With this design approach we think we can support users in better understanding the reasons leading to the actual ranking, as well as providing them with a rationale for following specific suggestions. We also think that such an approach (provided the messages are designed well) could also highlight important criteria for making route decisions, thus helping users to re-evaluate their implicit decision structure and weighting of factors influencing trip mode decisions.

Of course there are certain limitations in this research. First, the time frame of our trial was relatively short in order to reveal strong evidences of behavioural changes and we didn’t have the chance to monitor the habits of the users before our intervention. A longitudinal study can shed light in the long term effects of our approach. Furthermore, our trial was based in Vienna, a city that offers a well-developed public transportation network. Transferring our results to cities or areas with fewer options can be cumbersome.

Also, the time of trial might have influenced the results and limited the possibility to generalize the findings to other times of the year. The trial was performed during summer, which is the main holiday season in Vienna, and traffic is generally much lighter than during school season, both for car traffic as well as on public transportation. Also, the weather typically is more inviting for biking than e.g. in winter, and therefore uptake of route suggestions might vary from the findings of a study done in winter.

6. Conclusions and Future Work

In this paper we developed an approach that encourages green transportation habits by guiding and supporting urban travellers in finding trips that cause low emissions, based on persuasive technologies supported by concepts of choice architecture. Our approach was instantiated in a smartphone application that was used in a real life trial setting by a group of users in the city of Vienna, Austria. The evaluation results were positive, showing acceptance of our approach and increased environmental impact awareness.

For future research we plan to address the issue of non-rational factors that prevent behaviour change, such as habits, by using the choice architecture to better support self-reflection on the effects of personal acts prior to doing them and by using extended feedback mechanisms. To address social conditions, we furthermore plan to leverage social decision support in such way that we use social comparison and social learning to assist users in exploring sustainable travel alternatives.

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8. References

Avineri, E. (2009). Nudging Travellers to Make Better Choices. *International Choice Modelling Conference*. Last retrieved November 21, 2014 from http://www.icmconference.org.uk/index.php/icmc/icmc2009/paper/viewFile/148/50.

Avineri, E. (2012). User Interpretation of Travel Information and Implications for System Design. In *Proceedings of the 6th ACM workshop on Next generation mobile computing for dynamic personalised travel planning* (pp. 1-2). ACM.

Cialdini, R.B. (2001). Harnessing the Science of Persuasion. *Harvard Business Review*, *79*(9), 72-81.

Cofaru, C. (2011). Strategies of Developing Road Transport by Controlling Automotive Emissions to Reduce Local and Global Environment Impacts. In *Proceedings of 6th IASME/WSEAS International Conference on Energy & Environment* (pp. 23-25).

Cremonesi, P., Donatacci, A., Garzotto, F., & Turrin, R. (2012). Decision-Making in Recommender Systems: The Role of User's Goals and Bounded Resources. In *Decisions@ RecSys* (pp. 1-7).

Diehl, K., Kornish, L.J., & Lynch Jr, J.G. (2003). Smart Agents: When Lower Search Costs for Quality Information Increase Price Sensitivity. *Journal of Consumer Research*, *30*(1), 56-71.

DiSalvo, C., Sengers, P., & Brynjarsdóttir, H. (2010). Mapping the Landscape of Sustainable HCI. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1975-1984). ACM.

Fielding, K. S. & Head, B.W. (2011). Determinants of Young Australians Environmental Actions: The Role of Responsibility Attributions, Locus of Control, Knowledge and Attitudes. *Environmental Education Research*, *18*(2), 171-186.

Fogg, B.J. (2002). Persuasive Technology: Using Computers to Change what We Think and Do. *Ubiquity*, 2002, 5.

Froehlich, J., Dillahunt, T., Klasnja, P., Mankoff, J., Consolvo, S., Harrison, B., & Landay, J. A. (2009). Ubigreen: Investigating a Mobile Tool for Tracking and Supporting Green Transportation Habits. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1043-1052). ACM.

Froehlich, J., Findlater, L., & Landay, J. (2010). The Design of Eco-Feedback Technology. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1999-2008). ACM.

Gabrielli, S., & Maimone, R. (2013). Digital Interventions for Sustainable Urban Mobility: A Pilot Study. In *Proceedings of the 2013 ACM Conference on Pervasive and Ubiquitous Computing Adjunct Publication* (pp. 119-122). ACM.

Goldstein, D.G., Johnson, E.J., Herrmann, A., & Heitmann, M. (2008). Nudge Your Customers Toward Better Choices. *Harvard Business Review*, *86*(12), 99-105.

In-Time: Intelligent and Efficient Travel Management for European Cities. Last retrieved December 14, 201] from http://www.in-time-project.eu/.

Iyengar, S.S. & Lepper, M.R. (2000). When Choice Is Demotivating: Can One Desire too Much of a Good Thing? *Journal of Personality and Social Psychology*, *79*(6), 995-1006.

Johnson, E.J., Shu, S.B., Dellaert, B.G., Fox, C., Goldstein, D.G., Häubl, G., Larrick, R.P., Payne, J.W., Peters, E., Schkade, D., Wansink, B., & Weber, E.U. (2012). Beyond Nudges: Tools of a Choice Architecture. *Marketing Letters*, *23*(2), 487-504.

Kimura, H. & Nakajima, T. (2011). Designing Persuasive Applications to Motivate Sustainable Behavior in Collectivist Cultures. *PsychNology Journal*, *9*(1), 7-28. Retrieved December, 2014.

Kollmuss, A., & Agyeman, J. (2002). Mind the Gap: Why Do People Act Environmentally and What Are the Barriers to Pro-Environmental Behavior? *Environmental Education Research*, *8*(3), 239-260.

Levav, J., & Iyengar, S.S. (2008). Order in Product Customization Decisions. In *Proceedings of the Society for Consumer Psychology 2008 Winter Conference* (p. 168).

MIT SENSEable City Lab: CO2GO. Last retrieved December 10, 2014 from http://senseable.mit.edu/co2go.

Reitberger, W., Ploderer, B., Obermair, C., & Tscheligi, M. (2007). The Percues Framework and Its Application for Sustainable Mobility. In *Persuasive Technology* (pp. 92-95). Heidelberg: Springer.

Schahn, J., Damian, M., Schurig, U, & Füchsle, C. (2000). Konstruktion und Evaluation der dritten Version des Skalensystems zur Erfassung des Umweltbewusstseins (SEU-3). *Diagnostika*, *46*(2), 84-96.

Steg, L. (2005). Car Use: Lust and Must. Instrumental, Symbolic and Affective Motives for Car Use. *Transportation Research Part A: Policy and Practice*, *39*(2), 147-162.

Thaler, R.H., Sunstein, C.R., & Balz, J. P. (2010). Choice Architecture. Last retrieved July, 2012 from http://www.sas.upenn.edu/~ baron/475/choice.architecture.pdf.

Torning, K., & Oinas-Kukkonen, H. (2009). Persuasive System Design: State of the Art and Future Directions. In *Proceedings of the 4th International Conference on Persuasive Technology* (p. 30). ACM.

Wiafe, I., & Nakata, K. (2012). Bibliographic Analysis of Persuasive Systems: Techniques, Methods and Domains of Application. *Persuasive Technology*, *61*.

Wilson, C.M., Garrod, L., & Munro, A. (2013). Default Effects, Transaction Costs, and Imperfect Information. *Economics Letters*, *119*(2), 213-215.

Worsley, A. & Skrzypiec, G. (1998). Environmental Attitudes of Senior Secondary School Students in South Australia. *Global Environmental Change*, *8*(3), 209-225.