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AFFORDANCES AND ENVIRONMENTALLY SIGNIFICANT BEHAVIOR

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ABSTRACT
In this paper, we apply design-by-affordance methodology to the problem of environmentally significant behavior. Affordances, as originally formulated, represent opportunities for action offered by a product. Subsequent work explored the use of affordances, defined as context-dependent relations between artifacts and users, in lieu of functions as a basis for design. While others have also developed detailed deductive methods of discovering affordances in products, we present *affordance listing* as an expedient technique for inductively discovering relevant affordances. We also present *affordance transfer*, a method for redesigning products to encourage environmentally significant behavior. We conclude by discussing insights gained from applying our two approaches.

1. AFFORDANCES
When users encounter an unfamiliar product, they may have difficulty determining how to use it. The concept of affordances is helpful for understanding how these problems occur. In simplest terms, an affordance is a possible way of interacting with a product, e.g., an object with a low, flat surface affords sitting and the resting of objects. When users cannot see the affordances in a product, they may have difficulty using it. We will describe two techniques, the first intended to find important affordances in a product quickly and the second to provide affordances to influence user behavior. First, we summarize major developments in the study of affordances.

1.1. Developments in the study of affordances
Gibson (1979), a perceptual psychologist, formulated the concept of affordances to describe complementary relationships between an animal and its environment (Scarantino 2003). For example, a rock face may afford shelter for one animal or a surface for climbing to another.

Norman (1988) introduced affordances to the field of product design, and defined them as the set of *action opportunities* provided by a product. A knob provides the opportunity for turning. A car provides the opportunity for driving. Norman (1999) also developed the notion of *perceived affordances,* "actions the user perceives to be possible" with a product, and contrasted them with *real affordances,* actions that are actually possible with the product. When discrepancies arise between real and perceived affordances, the user experience can be compromised. Specifically, a user may expect to be able to perform an action that is not actually possible, or a user may not recognize that a particular action is possible with a product.

Maier and Fadel (2009a) made affordances, defined as "potential uses" of a product, the basis of a formal design process. Affordances possess certain advantages over functions, the more commonly used basis for design. In strict terms, functions describe transformations of energy or matter, e.g., pumping oil or turning a wheel, and require inputs and outputs. User needs that are more difficult to articulate as transformations with an input and output are more easily expressed as affordances. The broad definition of "potential uses" also allows affordances to subsume functions, i.e., a product's functions are included in the set of its affordances.

Pols (2011) categorized affordances into four groups with differing complexity. The simplest are *manipulation opportunities* (e.g., a button affords pressing). Next are *effect opportunities* that describe the possible effects of using the product (e.g., a hammer affords breaking a glass pane). Higher still are *use opportunities* that represent the tasks users can imagine completing by using the product (e.g., a drill affords the insertion of screws into a piece of furniture). Highest are the *activity opportunities*. These are higher-level outcomes from the use of a product (e.g., a showerhead affords cleanliness). We will continue with Pols' definitions in our work.

1.2. Affordance polarity and affordance-based errors

Norman (1988) and Maier and Fadel (2006, 2009a, 2009b) assign polarity to affordances. Positive affordances help the user and negative affordances harm the user. The notion of polarity is helpful for designers to categorize affordances as either desirable or undesirable. We use a similar definition for affordance polarity, only one more explicitly linked to users' needs. Affordances that meet users' needs and enhance their use experience are positive, whereas affordances that interfere with users' needs and degrade the use experience are negative.

Norman (1988) catalogued common frustrations that people face when interacting with everyday products. The difficulty in programming a VCR, understanding how a shower control works in a foreign country, or even knowing whether to push or pull a door open can all be caused by a lack of affordances and/or the presence of misleading affordances. We term such cases affordance-based errors, which represent discontinuity between designers' intentions and users' perceptions.

1.3. Using affordances in the design process

The benefits of systematizing the design process are well demonstrated (Hauser and Clausing 1988; Pahl and Beitz 2007). Maier and Fadel (2006, 2009a, 2009b) have developed a systematic design method based on affordances. Similar to function-based methods, user needs are first collected using surveys, focus groups, etc. The needs are then converted into affordances, and concepts are developed that provide the necessary affordances. The affordances of the concepts are analyzed, compared to user needs, and their design modified as necessary, until a final concept is developed. Apart from a few steps, this method is structurally similar to well known function-based design methods.

The benefit of using affordances is also apparent for product redesign (Brown and Blessing 2005). Once an embodiment has been created, finding all of its affordances helps designers understand all the actions a user could perform with it. Designers can then alter the design to help the users use, or prevent them from using, the product in particular ways.

2. FINDING AFFORDANCES

Transforming user needs into affordances is a fairly straightforward process. Finding the affordances of a concept or an existing product design can be more difficult. Maier and Fadel's method (2006) takes advantage of the designer's experience and product knowledge to analyze and identify a concept's affordances. Nevertheless, the difficulty designers face when trying to view a design from the user's perspective (Kouprie and Visser 2009) may cause them to miss some relevant affordances. To address this concern, other methods rely on the users themselves to provide designers with the affordances in a concept. Galvao and Sato (2005) used several interview-style methods to generate a list of affordances for a blender and its component parts. Participants were first asked to speak aloud while using the blender to make a mixed beverage. They were then asked questions about each component of the blender in order to understand the possible tasks they could imagine using it for. This use observation, combined with a thorough review of the product architecture, produced a large set of affordances. Hsiao et al. (2011) built on Galvao and Sato's work by creating an online survey system for determining affordances for products. In each survey, participants were shown one component and asked to select the affordances they felt best matched it. The data was then analyzed and prioritized statistically to produce a master list of affordances associated with the product. While more exhaustive than relying on designers' knowledge alone, these user-based methods are more time- and effort-intensive, especially if they must be repeated for multiple concepts for a single design.

3. AFFORDANCE LISTING BY GROUP SIMILARITY

In this paper, we propose a new method for quickly determining the main affordances associated with a product. Designers can then enhance or diminish these affordances to meet users' needs and prevent affordance-based errors. We can quickly find the salient affordances of a product by studying:

i. Products in the same superordinate category
ii. Products used in the same context
iii. Products with the same intended purpose

Considerable overlap in the affordances generated using the different methods is likely as products in the same superordinate category will often be used in the same context or have the same intended purpose. The goal of using multiple methods is to maximize the number of unique salient affordances.

In each method, we express affordances in terms of the manipulation, effect or use opportunity perceived by a user. Past researchers have described affordances in varying ways. For example, a shoe can be used for holding a door open. Some researchers (Lim and Kim 2009) describe that affordance using Gibson's [verb phrase]-able or [verb-phrase]-ability construct, i.e., it has *hold-a-door-open-ability* (Scarantino 2003). Others describe it as a noun phrase, i.e., it must afford *holding-open* to *doors*, (Maier and Fadel 2009a). We construct affordances using the present participle of the main verb, i.e., *door holding*.

3.1. Similarity in superordinate product category

The first method involves finding affordances by examining products from the same higher-order functional category. Affordances are often reproduced among products in the same superordinate category. For example, in optimizing the design of a screwdriver, one may first identify all the potential actions a user can perform with it. Besides the obvious actions of driving fasteners and opening paint cans, screwdrivers may also afford striking, making crude measurements, stirring mixtures or scraping. These affordances are shared by other products in the same superordinate category, namely that of hand tools. Designers can generate these affordances by thinking of the main affordances of related tools, in a faster way than would be possible using previously described methods. Figure 1 lists affordances of products that fall in the same superordinate category with affordances applicable to screwdrivers shaded in black. The list can be used in several ways. Designers could enhance existing affordances to improve the user experience, e.g., add a ruled scale to the shaft to enable more precise measurements, or eliminate affordances that are likely to lead to a degraded user experience, e.g., reduce the weight of the handle so that it cannot be used for striking.

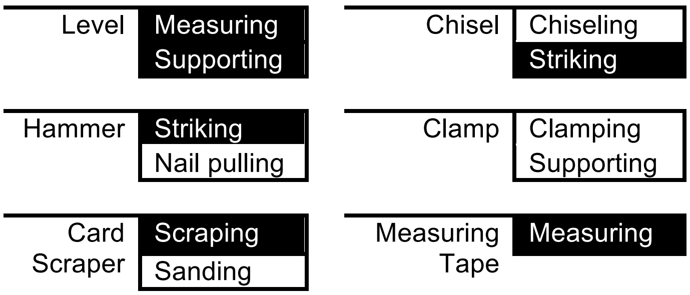

Figure 1: Affordance listing by superordinate category for screwdrivers.

3.2. Similarity in context

Affordances are also shared between products used in the same context. Context can refer to the physical location where the object is used or stored, e.g., a product that is kept on a desk might afford the same actions as other desktop products, or can refer to the activity with which a product is associated, e.g., a product used in the sport of tennis might afford other tennis-related tasks. For illustration, consider the example of a bed, which is typically stored and used in a bedroom. Other products used in the same context include chests of drawers, nightstands, chairs, lamps, etc. Figure 2 shows that a bed offers many of the same affordances (relevant ones are shaded black). Designers could once again enhance these affordances to improve the user experience, e.g., adding cross planks to aid in the hanging of clothes or adding storage space below the bed.

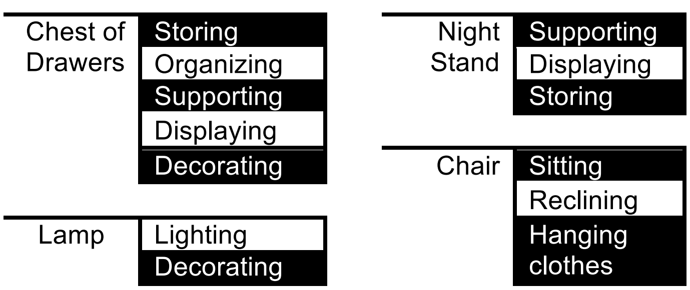

Figure 2: Affordance listing by context for beds.

3.3. Similarity in intended purpose

Products intended for similar purposes also tend to have overlapping affordances. For illustration, consider the example of scissors, whose main purpose is cutting. Other products that cut include pruning shears, kitchen knives and utility knives. Figure 3 shows that the main affordances of scissors are found among the affordances of other products with the same purpose. As with the other methods, designers can enhance some affordances to meet user needs better, e.g., by adding the ability to retract the cutting edges, or remove affordances which detract from the users' needs, e.g., by rounding the blade ends so that they are more difficult to use for piercing.

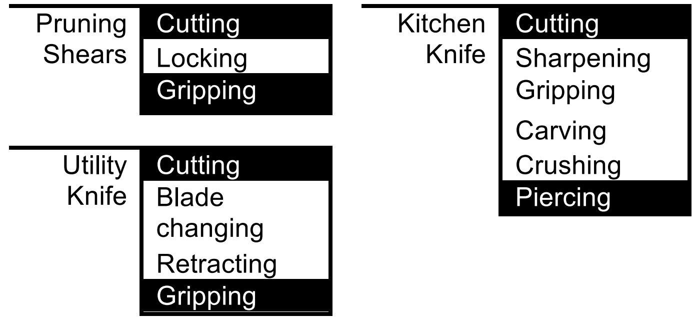

Figure 3: Affordance listing by similarity in intended purpose for scissors.

3.4. Summary of affordance-listing methods

Affordance listing allows designers to quickly determine the affordances relevant for the redesign of a product. We estimate that most users tend to mentally perceive products within groupings of superordinate category, physical context and intended purpose. By limiting attention to those areas and supplementing with user observations and interviews, designers can generate a large list of relevant affordances in a short amount of time. Designers can then rate each affordance on severity, e.g., the potential of a negative affordance to violate a user need. It is also important to realize that, as with other methods, designer experience will contribute to the level of effectiveness of this approach. Experienced designers will be more knowledgeable and able to think of similar products and determine their affordances quickly. That said, even novice designers should be aided by this method as they can rely on tools such as retail website categories or industry groupings to generate their lists.

4. AFFORDANCE TRANSFER

As we noted in the examples for the affordance-listing methods, designers can modify a product's affordances to improve users' experiences by better meeting their needs. Designers can also take a more prescriptive approach with affordances, i.e., they can use the affordances of a product to encourage users to behave in particular ways. Next, we present a way that designers can modify affordances to help users behave in more environmentally conscious ways.

4.1. Environmentally significant behavior (ESB)

This work is motivated by the fact that the costs of energy, water and other resources will increase greatly in the future (Aleklett et al. 2010). Consequently, a great deal of engineering effort has been expended in designing more resource-efficient products. Still, researchers have found that the availability of more efficient products can actually cause users to be more complacent about the use of those products, so that the overall consumption continues to rise after an initial decline. This is known as the *rebound effect* (Herring 2006). As an example, the increasing fuel efficiency of cars has in fact led to people driving more frequently and for longer distances than before. Sorrell et al. (2009) suggest that as efficiency increases, the mentally perceived worth of a resource declines, making people more inclined to use the resource. Therefore, in addition to creating more efficient products, designers should also make products that change users' behavior. To effectively reduce resource consumption, users must be encouraged to use resource-consuming products less and for shorter durations.

Such user behaviors have been categorized by Stern (2000) in his *Environmentally Significant Behavior* framework (ESB). The framework defines ESB as any behavior that people engage in that has an effect on the material and energy flows of the environment. These behaviors may be active (joining an environmentalist group) or passive (accepting a retailer's bag-free policy), intentional (using public transportation) or unintentional (purchasing an environmentally better product for other reasons) and public (participating in a demonstration) or private (sorting and recycling household waste). The goal of our research is to encourage and facilitate such behaviors (Srivastava and Shu 2011, 2012; Son and Shu 2012). Designing products that encourage behavior change is difficult because users are often accustomed to performing a task or using a product in a particular way. Changing the way they interact with the product therefore requires overcoming a great deal of inertia. We believe the affordance-transfer method provides a way of encouraging behavior change through product design.

4.2. Principles to support ESB

In our previous work, we discovered three general design principles that work in encouraging and facilitating ESBs: *discretization, transformation, and localization*. Our aim is to use affordance transfer to implement each of these principles.

4.2.1. Discretization

Studying how Old Order Mennonite communities conserve resources revealed that many of their resources that exist in discrete units, e.g., logs of wood, tend to have continuous analogs in the modern world, e.g., electricity. We confirmed that users presented with resources in discrete units, e.g., water in cups instead of continuously from a faucet, conserved that resource more effectively (Srivastava and Shu 2011).

4.2.2. Transformation

Furthermore, we have seen that products that embody the transformation principles identified by Singh et al. (2009) i.e., expand/collapse, reveal/conceal, fuse/divide, often facilitate environmentally significant behaviors (Son and Shu 2012).

4.2.3. Localization

Finally, the principle of localization has been shown to be effective in helping users engage in ESB. When Momoh (2011) studied how a group of people (lead users) maintained thermal comfort in an office without air conditioning in the summer, he discovered that they used various techniques for local cooling e.g., small desktop fans, and changing body position to promote greater heat transfer. This reduced their overall energy consumption, as the entire space no longer required cooling.

4.3. Affordance transfer to support ESB

The process of transferring affordances comprises 5 steps:

0. ESB selection

We first select an ESB we wish to enable.

1. ESB context analysis

In this phase, we analyze the ESB, examining the activities and products associated with that behavior. This can be accomplished via traditional needs analysis methods such as task analysis, interviews and user observation. The purpose of this phase is to identify products that are obstacles to that ESB.

2. Obstructing product affordance definition

We then select one obstructing product and determine its affordances using the above affordance-listing methods.

3. ESB-compatible product search

To understand which affordances would facilitate the ESB, we find a product that enables the ESB. We then list the affordances of the ESB-compatible product.

4. Affordance transfer

Comparing the affordances of ESB-compatible products with those of the ESB-obstructing product, we use concept generation methods to find ways of importing affordances from ESB-compatible products into the ESB-obstructing products.

We now present the affordance-transfer method applied to the three ESB-enabling design principles

4.4. Discretization as a mechanism for affordance transfer

4.4.1. Discretization example 1

<u>0: ESB selection</u>

Encouraging users to reduce domestic water consumption.

<u>1: Context analysis</u>

One of the largest contributors to domestic water use in North America is bathing, and more specifically showering. Reducing the amount of water used while showering would have significant effect on overall water usage. In addition, many users are unaware of the amount of water they consume while showering, and when presented with the information, do not have an appreciation for the significance of the quantity.

<u>2: Obstructing-product-affordance definition</u>

Our initial assessment of showerheads and controls affordances is shown in Table 1. We also reviewed products in the same superordinate category (kitchen and bathroom faucets), context (toilets) and intended use (water coolers, water fountains).

Table 1: Affordances for shower controls.

Product	Affordances
Showerheads	Adjusting flow orientation Adjusting flow pattern
Shower controls	Adjusting temperature Adjusting flow rate

The affordances related to showering provide the user with the ability to monitor neither the quantity of water use, nor the flow rate. It was interesting to note that the superordinately related products, e.g., faucets, feature affordances for controlling the temperature as well as rate of flow while most shower controls only allow control of temperature. We were unable to find products in any of these categories that afforded monitoring of the amount of water used. It is therefore understandable that users can have difficulty moderating their water usage during showering.

3: Compatible-product search

In this case, the ESB we wanted to facilitate involved users being able to track and thus limit their water usage. We found a relevant example in the context of camping. Many camping activities are less resource-intensive versions of daily home activities. Products such as camping showers, drink coolers and sleeping bags allow users to perform domestic activities while abiding the resource, energy and space constraints of camping. Camping showers in particular allow the conservation and tracking of water usage. They consist of a sealed bag, dark colored to better absorb heat, connected to a tube with a valve. The bag can be hung from a high location and the user opens a valve to allow water out. The amount of water used in the operation of a camping shower is much lower than that of a typical domestic shower. The relevant affordances of camping showers are listed in Table 2.

Table 2: Affordances for camping showers.

Product	Affordances
Camping showers	Limiting amount of water used Adjusting flow rate Controlling orientation Hanging Indicating amount of water remaining

4: Affordance-transfer ideation

Two main affordances of camping showers appear to be instrumental for encouraging users to minimize water usage: *limiting the amount of water used* and *indicating the amount of water remaining*. Figure 4 shows a concept that makes use of these affordances, featuring a transparent container of fixed capacity connected to a showerhead. Water enters the container from the main source and the user can fill the container to a desired level before showering. The water then flows from the container through the showerhead that allows adjustment of flow rate and orientation. Additionally, the markings on the container allow the user to track the rate of water usage.

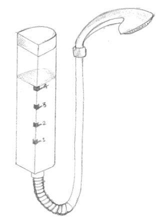

Figure 4: Water-conservation-enabling shower product.

4.4.2. Discretization example 2

0: ESB selection

Encouraging users to turn off electronic devices in the home such as televisions to conserve energy.

1: Context analysis

Entertainment devices such as televisions often remain on for long periods of time, even when they are not actively being used. Users are typically unaware of the amount of energy these devices consume, and often forget/neglect to fully turn them off.

2: Obstructing-product-affordance definition

Table 3 shows our analysis of the affordances of television sets. We examined products in the same superordinate category (microwave ovens, stereos), context (sofas, coffee tables) and with the same intended purpose (cellular phones, computers). Although televisions often have delayed-off features, they are rarely used.

Table 3: Affordances for televisions.

Product	Affordances
Television	Turning on and off Changing channels Attaching Providing sound and light Setting sleep setting Adjusting volume Adjusting picture Selecting menu options

3: Compatible-product search

Many battery-powered electronic products such as laptops and cell phones do facilitate turning off when not in use. Features such as standby mode or automatically turning off after a set period of time greatly reduce energy usage. While many televisions come with timer functions, this feature is often not prominent or not used frequently.

In earlier sections, we noted that users needed to be reminded to turn off devices. For this purpose, we looked at alarm clocks. Alarm clocks are interesting because they are predominantly timers that turn themselves off and on at user-set times. In addition to displaying time and its passage explicitly, alarm clocks enable users to discretize and track the passage of time through the use of a snooze button.

Table 4: Affordances for alarm clocks and cell phones, etc.

Product	Affordances
Alarm Clock	Displaying time and its passage Discretizing and tracking time elapsed by "snoozing"
Cell phones, laptops, etc.	Automatically switching into energy conserving modes after inactivity Displaying level of energy remaining

4: Affordance-transfer ideation

We developed a concept using the affordances of switching off automatically and providing periodic reminders to turn off devices. The concept replaces the power button on the television with a timer/snooze button that turns on the device for discrete time periods. When the device is powered up, a timer begins to count down. The times for each device can be user-programmed based on his or her use and energy saving goals, e.g., a television could turn off after an hour. When the countdown reaches zero, the device will shut off. Pressing the snooze button during the countdown provides the user with a fixed amount of extra operation time, e.g., half an hour, for the device. Thus, users will be able to better track the amount of time a device has been on and therefore the energy consumed.

In addition or alternatively, the television screen can be made to darken gradually (rather than suddenly as the case of computer and cell phone screens), where user interaction, e.g., pressing a button on the remote, restores it to its full brightness. This allows people who use televisions primarily as background noise to do so with less energy expenditure.

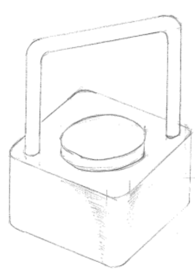

Figure 5: Snooze button television concept.

4.5. Transformation as a mechanism of affordance transfer

4.5.1. Transformation example 1

0: ESB selection

Encouraging parents with young children to take public transit rather than drive.

1: Context analysis

Taking public transit with young children can be challenging for many parents. Young children who cannot walk for long distances need to be carried. Parents of young children must also travel with child-care items, e.g., bottles, diapers, additional clothes, etc. Navigating crowded public-transit platforms with such loads can be difficult. Taking public transit also requires maneuvering through a variety of terrain while getting on/off and moving between buses or trains and going up/down stairs or escalators. It is understandable why many parents prefer to travel by car in these circumstances.

2: Obstructing-product-affordance definition

One of the most common ways of transporting small children and child-care items is by stroller or pram. These products are difficult to use in crowded public transit systems. Although wheelchair accessibility, and therefore stroller accessibility, of public transit has increased in past years, ramps are still not available at all public transit stations and elevators can be difficult to locate and far from the main points of entry and exit. Strollers can also have difficulty traversing over large obstacles and bumps as well as through narrow doorways, turnstiles and revolving doors. The child can be removed from the stroller, but having to carry both either at the same time or in multiple trips is almost as burdensome and creates unique risks. Table 5 lists the affordances we found for strollers. We looked at products in the same superordinate category (cribs, baby monitors, childproof gates), context (baby bottles, diaper bags, baby carriers) and purpose (shopping cart, wheelbarrow).

Table 5: Affordances for strollers.

Product	Affordances
Stroller	Transporting over flat ground Rolling smoothly Changing direction Organizing Storing Hanging items

3: Compatible-product search

Other products designed for travelling are much easier to use in conjunction with public transit. Backpacks (also known as book-bags or knapsacks) are often carried by transit users and travelers while transporting a wide variety of items. They are typically carried on users' backs but many also feature wheels for rolling. Additionally, many backpacks include separable and removable compartments.

Table 6: Affordances for luggage.

Product	Affordances
Large Backpack	Storing Carrying on the back/front Rolling Organizing Dividing

4: Affordance-transfer ideation

It is apparent that strollers can be made more transit friendly by adding the ability to be carried on the back/front of users. Front/back pack style child carriers are already available, but for travel over long distances over flat ground, rolling on wheels is clearly preferable.

We noted that such a product, one that combined the ability to roll with the ability to be carried on user's backs/fronts, had been designed as part of an undergraduate design thesis project (Son 2010). This transit-friendly baby stroller aimed to remove obstacles related to using public transportation while traveling with a stroller and child. The concept employed the fuse/divide transformation principle whereby the child-carrier part could be separated from the wheeled frame. The child-carrier component featured straps allowing the parent to carry their child securely while still having their arms and hands free to carry all the other items with which parents travel. The wheeled frame could be folded and carried separately. Figure 6 shows the concept.

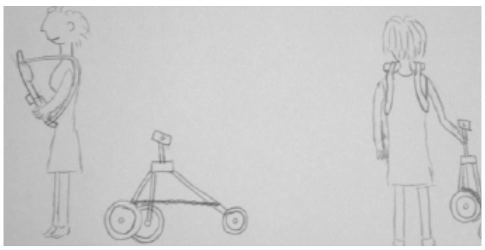

Figure 6: Transit friendly baby stroller (Son 2012).

4.5.2. Transformation example 2

0: ESB selection
Encouraging people to use public transit instead of driving/taking a cab to and from the airport.

1: Context analysis
Many major cities such as Copenhagen, Chicago, and Atlanta have public transit connections directly available from the airport. There is also a financial incentive to engage in this ESB as public transit is usually cheaper than taking a taxi. Nevertheless, there are many obstacles for travelers to using public transit. Subway stations are not guaranteed to have a working escalator, much less elevator, almost necessary when carrying luggage. Transfer points can have especially long flights of stairs to navigate if escalators are not working, and elevators, if available, may not be clearly marked or easily accessed. Therefore, unless one is prepared to carry everything up or down a flight of stairs, it is ill advised to take public transit to and from airports in general. Experienced business travelers can learn to pack efficiently, but requirements for business clothing and equipment limit how little one can pack.

2: Obstructing-product-affordance definition
In addition to business clothing and equipment, a more formal winter coat, necessary in the cold months, can add significantly to one's load. It is undesirable to wear such a heavy coat while carrying luggage up and down stairs, and carrying such a coat either separately or within luggage is also a significant burden. Table 7 lists affordances of formal winter coats. We examined products in the same superordinate category (shirts, jackets), context (winter boots, hats, scarves) and with the same intended purpose (umbrellas, blankets).

Table 7: Affordances for formal winter coats.

Product	Affordances
Formal winter coat	Keeping one warm Keeping water out Looking dressy Covering a large part of the body

None of these affordances related well to the need to reduce weight and bulk to facilitate carrying.

3: Compatible-product search
We examined several products that use transformational strategies in order to facilitate easier transportation. Using light but durable fabrics, reusable shopping bags minimize their bulk by folding into a small pouch. Irregularly shaped items such as pool cues or trombones are made easier to transport by deconstruction into smaller parts. Table 8 lists the affordances for relevant products, with a focus on those related to our established goal of minimizing weight and bulk.

Table 8: Affordances of compatible products.

Product	Affordances
Reusable shopping bag	Folding Storing
Trombone	Deconstructing
Pool cue	Deconstructing

4: Affordance transfer
These affordances can be easily transferred to the design of a jacket. The redesigned jacket would consist of separate components, e.g., a waterproof shell with an insulating layer below. The shell could be made foldable and easy to compact in size. Similarly, the insulating layer could be compacted and carried separately. Depending on the weather conditions of their location, users could also wear only the outer shell, only the insulating layer or both. Many manufacturers already offer such multi-component jackets that are easier to carry and store, and thus use while traveling. However, less so than the components shown in Figure 7, many such jackets do not offer the "looking dressy" affordance required on business trips.

Figure 7: "Dressy" shell and insulating layer.

4.6. Localization as a mechanism of affordance transfer

4.6.1. Localization example 1

0: ESB selection
Encouraging office workers to reduce heating in winter.

1: Context analysis
A great deal of energy is used for heating office spaces in winter. Most office tasks that involve long hours of sedentary deskwork make it difficult for users to stay warm. Users can try to keep warm by wearing heavier clothing indoors, but may still feel cold in their extremities. Moreover, items such as gloves can seriously reduce user dexterity, which is needed for essential office tasks such as typing.

2: Obstructing-product-affordance definition
To determine the relevant affordances for the product, we examined products in the same superordinate category (surgical gloves, cycling gloves), context (hats, scarves, winter boots) and intended purpose (heating pads, pockets).

Table 9: Affordances for gloves.

Product	Affordances
Gloves	Putting on and taking off easily Pushing and gripping Keeping hands warm

3: Compatible-product search
The need for staying cool while working during the hot months is very similar to the need for staying warm while working in the winter. Products such as personal table fans are excellent at maintaining a comfortable working temperature locally without interfering with users' mobility or dexterity. Table 10 lists some relevant affordances of table fans.

Table 10: Affordances for localization compatible products.

Product	Affordances
Table fans	Directing air to desired location Changing intensity of output

4: Affordance-transfer ideation
If attention could be focused on keeping the hands warm, office workers would be able to perform their tasks even if the ambient temperature were lower than usual. We discovered a product that offers just this kind of affordance. The Thanko Corporation produces a USB powered keyboard heater that vents warm air from a wrist rest behind a keyboard. Users can direct the air to their hands and therefore be able to perform their work in cold conditions.

4.6.2. Localization example 2

0: ESB selection
Encouraging users to turn off lights to conserve energy.

1: Context analysis
Some light switches turn on a bank of lights simultaneously. Users therefore illuminate a general area when they might only need light in one specific area.

2: Obstructing-product-affordance definition
The obstructing product was found to be a light switch. We determined its affordances by reviewing products in the same superordinate category (thermostats, home alarm systems) and same context (televisions, ovens, air conditioners).

Table 11: Affordances for light switches.

Product	Affordances
Light switch	Easy flicking Controlling lighting for one area

Light switches and similar products are often limited in the amount of control they provide. While it is possible to have more individual switches as well as 3-way switches, retrofitting such hard-wired solutions may be expensive and difficult.

3: Compatible-product search
Certain electronic devices are better suited to allow users to localize their energy or resource usage, as well as locally access resources, e.g., networks, wirelessly. For example, laptop computers and cellular phones allow users to move them about without losing functionality. We developed the affordances for laptops and cellular phones relevant to localization.

Table 12: Affordances for localization compatible products.

Product	Affordances
Laptop	Easy carrying Localizing output via headphones Localizing input via wireless network
Cellular phones	Easy carrying Localizing output via headphones Localizing input via wireless network

4: Affordance-transfer ideation
Laptop computers and cellular phones provided a useful starting point to develop a concept that involves wirelessly monitored switches on individual lamps and other sources of light. When the user approaches one such source and decides to remain in the area near it, he or she can turn on the switch. The switch will automatically turn off all other lighting in the room, allowing the user to reduce energy consumption and ensure that light is available where it is most needed.

5. CONCLUSIONS AND FUTURE WORK

In this paper, we introduced two methods, affordance listing and affordance transfer. Affordance listing expedites one of the most time-intensive steps of design-by-affordance methods. By looking at other products in cognitively similar categories, designers can identify the most likely affordance overlaps for any product. We plan to verify the predictive efficacy of this method with actual users. Affordance transfer continues our efforts to use product design to enable environmentally conscious behavior. Altering a product's affordances to add functionality may be a useful way to approach product redesign, and transformation principles can play an important role in facilitating affordance transfer. Our next steps are to target additional types of ESB. Our work can benefit those tasked with promoting environmentally beneficial behavior change, as well as product companies that wish to capitalize on the segment of users who want to improve their environmental impact but are hindered by current product designs.

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