Packaging Technology and Science
An International Journal

PACKAGING TECHNOLOGY AND SCIENCE
Packag. Technol. Sci. 2015; **28**: 157–171
Published online 17 June 2014 in Wiley Online Library (wileyonlinelibrary.com) DOI: 10.1002/pts.2087

An Affordance-Based Methodology for Package Design

By Javier de la Fuente,[1†] Stephanie Gustafson,[2†] Colleen Twomey[3] and Laura Bix[4*]

[1]*Industrial Technology, California Polytechnic State University, San Luis Obispo, CA 93407, USA*
[2]*Abbott Nutrition, Columbus, OH 43206, USA*
[3]*Graphic Communication, California Polytechnic State University, San Luis Obispo, CA 93407, USA*
[4]*School of Packaging, Michigan State University, East Lansing, MI 48824, USA*

The term affordance describes an object's utilitarian function or actionable possibilities. Product designers have taken great interest in the concept of affordances because of the bridge they provide relating to design, the interpretation of design and, ultimately, functionality in the hands of consumers. These concepts have been widely studied and applied in the field of psychology but have had limited formal application to packaging design and evaluation. We believe that the concepts related to affordances will reveal novel opportunities for packaging innovation. To catalyse this, presented work had the following objectives: (a) to propose a method by which packaging designers can purposefully consider affordances during the design process; (b) to explain this method in the context of a packaging-related case study; and (c) to measure the effect on package usability when an affordance-based design approach is employed. © 2014 The Authors. *Packaging Technology and Science* published by John Wiley & Sons Ltd.

Received 30 April 2013; Revised 7 April 2014; Accepted 13 April 2014

KEY WORDS: packaging; design; affordance; constraint; usability; human factors

INTRODUCTION

From purchasing to disposal, human-package interactions are comprised of several steps that need to be accomplished in order to achieve varied goals. Optimal package designs inspire an immediate understanding of use, opening (where and how), proper and accurate dispensing, reclosure and disposal. This is particularly important for novel or unfamiliar packaging.[1] By definition, semantic issues, how users understand the meanings of a package, precede ergonomic issues, how users operate it.[2]

de la Fuente and Bix proposed a conceptual model to organize and analyse the complexities of human-package interactions. This model incorporates the four classical components of usability (i.e. user, pack, context and task) and recognizes the need to engage three user systems: the perceptual system, the cognitive system and the motor system. Our review of the literature regarding packaging usability suggests a lack of systematic research investigating perception and cognition as it relates to packaging use.[3] Further, it revealed that research is lacking in many of the distinct tasks performed with packages, with the vast majority concentrating on opening tasks, particularly emphasizing jars and bottles, and the physical actions (*motor system*) required to successfully achieve such tasks.

Aspects of user's perception and understanding of products have been addressed from a variety of fields such as psychology and product design. In the late seventies, the perceptual psychologist James

* Correspondence to: Laura Bix, School of Packaging, Michigan State University, 153 Packaging Building, East Lansing, MI 48824, USA.
E-mail: bixlaura@msu.edu
† Co-leading authors

Gibson revolutionized the field of visual perception by proposing that objects in the environment have functional meaning to an observer. Gibson invented the word *affordance* to describe any object's utilitarian function, defining affordances as relationships between the 'world and actors' (i.e. person or animal). Under Gibson's archetype affordances are all the 'action possibilities' latent in the environment independent of an individual's ability to recognize them.[4,5] Within this frame, the design features of an item, such as the pull tab of a can, have the potential to catalyse actions in the user (e.g. can opening). Instead of seeing a can with a pull tab, individuals could see an opportunity to open the can.

Donald Norman, a cognitive psychologist specializing in usability issues, drew on the theory of affordances and applied it to user–product interaction by introducing a narrower concept called *perceived affordances*.[6,7] Perceived affordances refer to the object characteristics (e.g. a design feature) perceived by users, which convey the ways that the user could interact with the object to accomplish an action. Form, colour, weight and the materials of an object incite possible user actions. These *perceived affordances* provide cues about the operation of things. When designers take advantage of affordances, people can intuit the use of an object without the need for instructions or explanatory labels. Catalysing appropriate perceived affordances through thoughtful design consideration is, therefore, a major key to usability. From this perspective, if a simple object needs instructions, its design is flawed.[6]

In the field of product design, there have been a number of theoretical attempts focused on conveying meaning through design. Two such theories are the *theory of product language*[8] and *product semantics*[9]; both of these theories incorporate the concept of affordances into aspects of communication related to product use. The first theory, *product language,* was developed in Germany by Jochen Gros and Richard Fischer within the Hochschule für Gestaltung Offenbach. It states that a product has two types of semantic functions; one related to its symbolism (symbol functions) and another to its usefulness and usability (indicating or marking functions). Product markings function to communicate the nature of the product (i.e. type of product or category) and how it should be used.[8] In the USA, Klaus Krippendorff and Reinhart Butter proposed *product semantics*.[9] Their approach includes a theory of human interfaces: how users understand products and interact with them. Under their view, affordances are 'building blocks' of the product interface with the capability of being perceived directly and effortlessly.[10]

BACKGROUND

Regardless of how (or if) they are communicated, affordances offer actionable possibilities to the user (i.e. actor). In order to understand how to utilize the theory of affordances to enhance functionality in packaging, the following sections clarify and review key concepts with the objective of familiarizing the reader with the field and its relevant theories.

Design principles

There are three design principles related to the perception of information that are critical for creating simple, usable package designs: the principle of visibility,[11] signal-to-noise ratio[12] and recognition-over-recall advantage.[13]

According to the *principle of visibility*, the usability of a product or system improves when possible actions (e.g. lift tab), and the subsequent result of the actions (e.g. to open), are clearly indicated by the design.[14] In the same way that written information on packages must be noticed to allow its mental processing,[11] specific design features of an object (e.g. the tab) must be clearly visible to the user and must convey precise messages (e.g. lifting this tab facilitates opening).[6] The features of a package must clearly communicate important information about how it functions and its current status.

The principle of visibility in design is a balancing act. On the one hand, a package's perceptual information must clearly elicit the appropriate actions to accomplish a task with the packaging. However, excessive information has the potential to overwhelm users. This has been defined as *signal-to-noise ratio*, the ratio of relevant to irrelevant information.[12] Optimal designs present relevant information at the time it is needed and reduce the load on cognitive resources, making processing easy.

People are better at recognizing things they have previously experienced than recalling them, without cue, from memory. Recognition memory is accomplished through prior exposure; it is simply something that has been experienced previously using the senses. Recall memory is achieved through memorization, practice and application. This design principle is described as *recognition-over-recall advantage*.[13] Under this theory, perceptual information should provide recognizable cues to the users to minimize cognitive load.

Affordances: design usefulness

Product designers have taken great interest in the concept of affordances because of the bridge it provides relating to a product's design, the interpretation of said design and, ultimately, its functionality. But there has only been limited, formal research that applies the concept to package design despite the obvious potential benefits of the approach.[15] To consider the relationship between users and design features within packaging, the term affordance in this paper is used as Gibson[4,5] proposed but expanded to include the concept of perceptual information offered by Gaver[16] and McGrenere and Ho[17] (Figure 1).

Affordances are generally described with words ending with '-ability'.[18] For example, the body of the package in Figure 3c affords 'grasp-ability', its trigger affords 'squeeze-ability' and the entire package affords the correct direction for 'aim-and-shoot-ability'. This conceptualization of affordances as general properties of an object is the basis for many affordance-based design approaches.[19–23]

The potential actions that design features enable, or 'afford' users in the form of action, as well as the communication of these actionable possibilities, and the efficiency with which the design feature enables the task, ultimately determines the usefulness and usability of an object: in our case, a package.[17] Those who design with affordances in mind purposefully consider the actionable possibilities embedded in the design (usefulness). But the design must also communicate the appropriate actions to most users so they can effortlessly understand (usability). The challenge for designers is to specify perceptual information in ways that minimize cognitive demand, favouring direct perception.

Affordances allowed by packaging features can be communicated leveraging varied senses. In packaging, these are generally the following: vision, audition and touch. However, designers should be encouraged to communicate the presence of affordance by creatively considering how each of the senses could be leveraged to communicate possible actions. Winder described the communication of the affordance by its signal of *strength* and *meaning*.[15] The strength of perceived affordances ranges from weak to strong. Weak affordances provide vague cues about how to operate an object, forcing users to focus on the task and use purposeful, effortful processing. The results of a package weakly communicating necessary actions to accomplish a task (e.g. the necessary removal of a clear, tamper-evident band by breaking small perforations located in a single location prior to opening) include: inconvenience, frustration, increased time, embarrassment and spills of contents, among others.

By contrast, strong affordances are so evident that minimal cognitive resources are needed to intuit the proper actions of use (e.g. drinking from the orifice at the bottle's top).[15] In terms of *meaning*, affordances can be true or false.[15] False affordances are inefficient and mislead the user, resulting in inappropriate actions, whereas true affordances provide clues that, if followed, will enable the successful completion of the intended task (i.e. opening, closing, pouring, etc.).

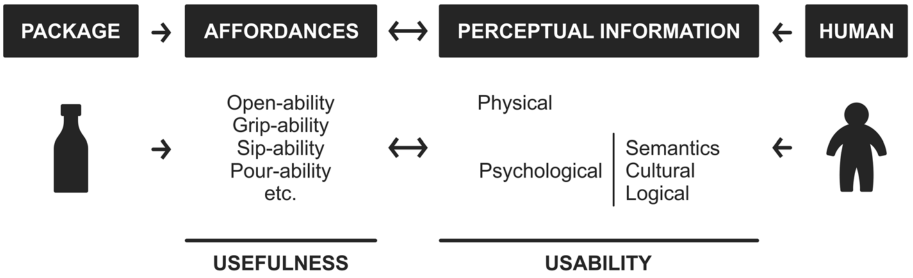

Figure 1. Affordances and their perceptual information. Adapted from McGrenere & Ho.[17]

DOI: 10.1002/pts

Perceptual information: design usability

According to Gibson's definition, affordances are specified by information.[4,16,17] They are independent of perception, existing whether or not they are perceived. That said, in order to be effective, they must be communicated through the senses (perception) to suggest the possibility of action. An affordance that does not convey its existence through perception is defined as a 'hidden affordance'.[16] Consider a clear, tamper-evident band with a small perforated area that enables it to be removed prior to opening the lug closure that lies beneath it. If the strength of its signal is so weak that the consumer proceeds directly to actions that support removal of the lug style closure, the tamper evident band's affordances are considered 'hidden'.

Hidden affordances frequently couple with false affordances to lead consumers to actions that are not at all in line with the designer's intentions. False affordances are misconstrued, conveying inappropriate actions to the user.[16] Consider a package of cookies consisting of a tray sealed inside a fin-sealed pouch. A section of the material above the tray allows the consumer to peel a portion of the pouch back, exposing a majority of the cookies in the tray for consumption. If the tab is hidden, the consumer may pinch and pull at the pouch's seal area to separate the seal so that the tray can be pulled out of the end of the pouch. The hidden affordance (the tab) and the false affordance (the seal) have worked together to create a situation where the consumer has performed in a way that is significantly different than the designer intended.

Interpretation of, and the definition for, 'perceptual information' varies. Galvao and Sato (2005)[19] classified it into two categories: *informative attributes,* which cognitively assist users in understanding product's functions, and *structural attributes,* which physically assist users in conveying appropriate physical actions (or affordances). The first group suggests behaviours using elements that derive meaning through purposeful cognition, such as text and symbols, whereas the second type is a construct derived by physical characteristic such as form, colour, material and layout.

Constraints

One way to optimize the perceptibility of affordances is through the use of constraints. Whereas affordances suggest a range of possible uses, actions and functions of an object (in our case a package), constraints limit possible actions, guiding users to identify the proper use of an object.[6,24] Well-designed constraints are most effective and functional when they are easy to perceive and understand so that restriction occurs prior to any action. Norman (1988) defined four different classes of constraints: physical, semantic, cultural and logical.[6] Lidwell (2010) recognizes two kinds of constraints: physical constraints and psychological constraints.[24] Lidwell's criteria is conceptually similar to the one used by Galvao and Sato[19] described before, structural attributes and informative attributes.

Physical constraints. Physical constraints rely on properties of the physical world (e.g. size, shape, weight, configuration, etc.) to limit the set of possible actions. This category includes constraints that redirect physical motion in specific ways by restricting possible operations.[6,24] Physical constraints are generally used on packages. Examples include perforated or scored lines for ease of tearing, grip zones for enhanced grasping (Figure 3c), sliders for ease of opening/closing on storage bags, tabs on lids for ease of pulling and so on.

Psychological constraints. Psychological constrains rely on the way people perceive and think about the world to limit the range of possible actions.[24] Examples are symbols or semantic constrains (i.e. symbols), cultural constraints (i.e. conventions) and logical constraints (i.e. mappings).

Semantic constraints rely on the meaning of the parts of a system to limit the range of possible actions. These types of constraints involve user's knowledge of the world to draw inference from known concepts and apply this inference to the existing design.[6] For example, the aerosol system depicted in Figure 3c conveys its operation (i.e. squeezing the trigger) by using a gun metaphor to communicate the correct grip position and direction of spray. Semantic constraints are not limited to the physical; they may be further supported by things such as symbols, warnings and colour that attempt to restrict possible actions by drawing inference from well-known concepts.

Cultural constraints rely upon accepted cultural conventions. Guidelines for cultural behaviour are stored in peoples' minds as knowledge structures made of rules and information that help to interpret and to guide behaviour.[6] A simple example of this in packaging is the continuous thread closure; even though there are physical constraints on them, the fact that users must rotate the cap counterclockwise for opening and clockwise for closing is a cultural convention.

Logical constraints are driven by reasoning. They rely upon logical relationships to limit alternatives of operation. An example of this type of constraint is natural mapping, where logical relationships exist between a spatial and functional layout of components and the things that they affect or are affected by.[6] For example, to avoid the use of explicit labels and enhance ease of use, stove controls are arranged following a layout that resembles the arrangement of the burners (Figure 2b). Consider the case of some child-resistant package designs, where users are required to push and turn the lid of a bottle. Before dealing with the physical effort of opening, users must understand first the logical sequence of operation. In child-resistant packaging, there are obvious physical constraints, which are invisible to the user, coupled with logical constraints that are explained by text on lids.

To illustrate how the concepts of affordance, perceptual information and constraints work in tandem to impact package usability, consider the evolution of aerosol design. A typical task regarding an aerosol can is comprised of aiming and spraying at a specific target. In the early years of aerosols, there were very few affordances built in to the design to guide the user to the appropriate aim (Figure 3a). The actuator afforded the action of downward pushing, which exposed the dip tube and dispensed the product. However, the constraints limiting the users to the appropriate direction of spray were non-existent (the actuator was flat). The design feature (a perceptual cue) that could be utilized was the small orifice area on the actuator's front. As the design evolved, designers began to incorporate some of the concepts discussed herein into the design, enhancing the likelihood of appropriate spray direction. Generations of aerosols produced during the 1990s incorporated a small angle (physical constraint), coupled with an arrow indicating the appropriate direction of spray into the actuator (Figure 3b). Although an improvement, this was still quite subtle; the possibilities to target the spray remained numerous, including the potential unintended action (i.e. spraying the user themselves, a negative affordance). In more recent years, introductions, such as the Febreze® Air Effects® aerosol can (Figure 3c), have taken the concept even farther. Its operation (i.e. squeezing the trigger) is conveyed by using a gun metaphor (semantic constraint). The trigger on the front affords squeezing (physical constraint), and the direction of use is constrained by this trigger and the plastic surface around the can's neck (physical constraint). This shape has geometrical characteristics such as a particular angle of inclination, a predominant axis of direction on the top and a smooth decrease in diameter that allows for only one power grip configuration in which the spray is naturally directed away from the user. Although all packages provide the user with strong affordances for either pushing down the actuator or squeezing the trigger to spray the package contents, differences in constraints differentiate packages with poor usability and one with enhanced usability.

Affordance-based design methods

Galvao and Sato (2005)[19] proposed three concatenated methods for linking product's technical functions, user's tasks and affordances. This approach uses task decomposition to help designers

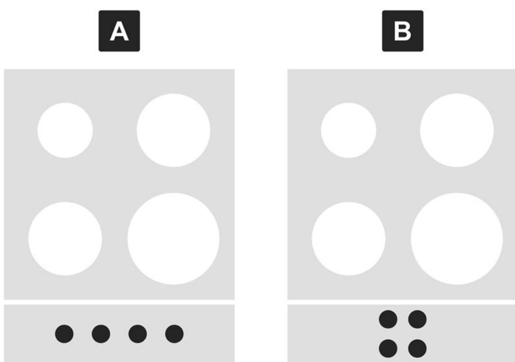

Figure 2. Logical constraints for stove controls: which knob controls what burner? (a) Arbitrary arrangement and (b) arrangement using natural mapping.

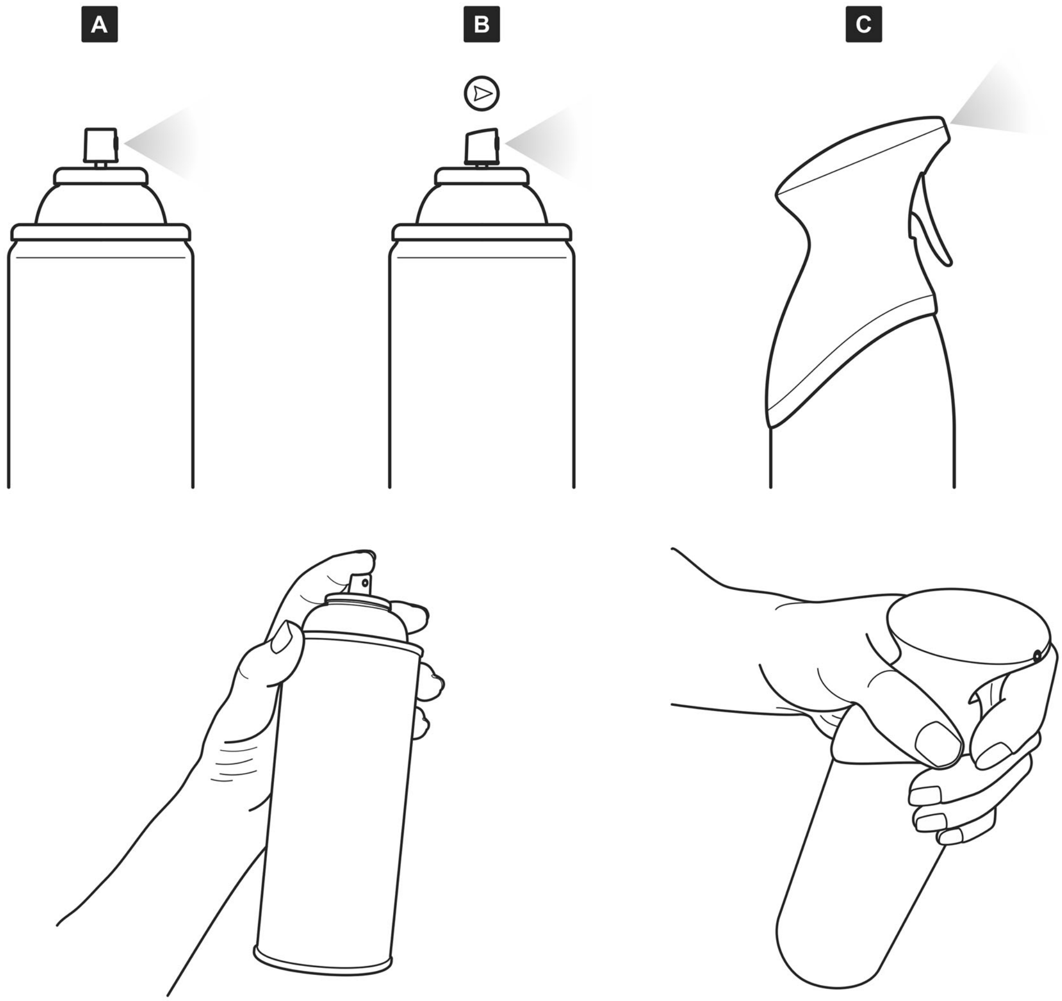

Figure 3. Affordances and perceptual information: (a) early aerosol, (b) modified aerosol and (c) Febreze® Air Effects®. Shape, materials and configuration of each package suggest the use of a particular grip style.

understand affordances and build solutions within for product and technical function–task interactions required. Those product and technical functions can include complex mechanisms that are not required for packaging. Therefore, the concatenated method and function–task interaction matrix proposed include layers of complexity that are unnecessary for packaging design and development.

Maier and Fadel (2009)[21] suggested a broad affordance-based design process that includes step by step methods for documenting affordances, methods for designing individual affordances, an affordance-based method for reverse engineering and redesign, the affordance structure matrix and affordance-based selection matrices. Authors proposed an affordance structure matrix that tallies positive and negative affordances within product-to-user and product-to-product interaction. Although packaging does require product-to-user and product-to-product interactions, the method's focus on the ratio of positive versus negative affordances adds complexity.

Hsiao *et al.* (2012)[25] proposed an affordance-based online tool to evaluate product usability in which a mathematical method is used for calculating affordance degrees. Authors claim that physical and online interactions yielded similar results and recommended that the online method be used instead of traditional evaluations to save time and costs. Their approach may be valid to evaluate some appearance features, but they failed to recognize an important limitation: an indirect visual interaction (i.e. users evaluating a product seen on a computer screen) is not the same as a real user-product interaction, with a physical product, in which all of the user's senses are involved.

DOI: 10.1002/pts

These existing affordance-based design methods are oriented to complex products with mechanisms. On the basis of the industry expertise of the authors, we believe that package designers and developers need a more straightforward and less technical method that can be applied to structural and graphic design of packaging. Many insights gained from the design research community can be leveraged to develop a model to assist packaging designers.

OBJECTIVES

Our objective is to develop a method that can be used to evaluate package designs considering users, context of use, affordances, tasks and design features. In the following sections, we propose an affordance-based methodology, use it with a case study, propose a redesigned solution and report the results of a usability test comparing the redesign against the original package.

METHODOLOGY

Building up on the method developed by Galvao and Sato (2005),[19] we proposed a methodology for testing user-package interactions from a usability point of view that is based on task analysis. The requirements for using it include a physical object (i.e. a package) and a design professional with basic understanding of affordances as they related to design and their perceptual information. The physical object could be a model/prototype under development or a commercially available package from the market. For a given package, the method consists of seven steps that can be included in a typical design process. They are as follows:

1. Identification of the context/s of use
2. Identification of patterns of use using a generic package use lifecycle (Figure 4)
3. Identification of subtasks using ethnography
4. Identification of affordances using task analysis
5. Identification of perceptual information for each affordance
6. Diagnostic
7. Generation of alternatives for design solutions.

Identification of context/s of use

A package may be used in one or several contexts of use (e.g. chaos, fast pace, calm, brightness, darkness, quiet, noisy, etc.). Identification of these will facilitate the next steps.

Identification of patterns of use

A pattern of use is defined as a specific combination of one or more general tasks depending on the user, package and context of use. From purchasing through disposal, the interaction between a person and a package consists of series of tasks, each involving a set of user actions. Figure 4 shows a generic package use life cycle as a starting point for the analysis. The arrows indicate possible paths of action.

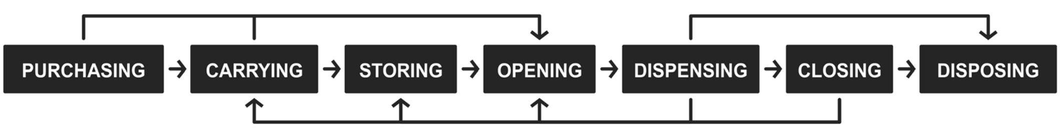

Figure 4. Generic package use life cycle.

DOI: 10.1002/pts

Identification of subtasks

Once that context of use and patterns of use have been identified, ethnographic research is used to observe, within the actual context of use, how users perform specific tasks. It is recommended that the same product trialling is carried out with varied typical users and those who are unfamiliar with the packaged product. Data collected in this step consist of video, audio and notes.

Identification of affordances

Using the ethnographic data collected during step three, patterns of use are broken into a series of tasks (and subtasks) and task analysis is performed (Table 1). For example, an opening task could be broken down in subtasks such as finding, gripping, pulling and tearing. Each subtasks is then associated to an action possibility or affordance, as previously defined. Continuing with the opening example, this would translate in four affordances: find-ability, grip-ability, pull-ability and tear-ability.

Identification of perceptual information

For each affordance identified in the previous step, one or more design features may be associated with it. The association between affordances and design features can be established by direct observation of users' actions and the package. Design features consist of physical and psychological perceptual information, as previously defined. The perceptual information involved is inferred from direct observation and by probing users after use.

Table 1. Identification of patterns of use, subtasks, affordances and possible perceptual information at play for one subject trial.

Pattern of use	Subtask	Affordance	Folding carton design feature	Possible perceptual information
Storing	Finding the package	Find-ability	All sides	Colour, text and package shape
	Grabbing the package	Grip-ability	All sides	Package shape
	Looking for space to grip	Grip-ability	Body	Package shape
	Grabbing the package with one hand	Grip-ability	Body	Package shape
Opening	Finding place to open	Find-ability	Body	Text orientation
			Top end	Top flap's edges and corners (Figure 5b)
	Tearing off the top flap of the top end	Tear-ability	Top end	Top flap's edges and corners (Figure 5b)
	Folding out inner flaps	Fold-ability	Top end	Inner flaps
Dispensing	Trying to grab syringe or vial		Inside	Inner division obstructing access
			Inside	Visual of vial and syringe
Opening	Finding place to open	Find-ability	Bottom end	Perforated edges
			Side panel	Legend 'OPEN'
			Front panel	Arrow and legend 'PRESS AND PULL TO OPEN'
	Pressing with finger	Press-ability	Side panel	Folding triangular flaps (Figure 5a)
	Grabbing bottom end flap	Grip-ability	Bottom flap	Flap's surface (Figure 5a)
	Pulling off flap	Tear-ability	Bottom flap	Perforated edges
	Discarding flap		Bottom flap	
Dispensing	Dumping contents on hand	Dump-ability	Opened end	Package shape

Diagnostic

The analysis of the data collected in step three allows designers to evaluate a design in the hands of people. Usability problems will become visible during task analysis in the form of unintended subtasks, negative and false affordances, or even the failure to complete the intended task. All these issues are linked to problematic design features that can be improved as needed.

Generation of alternatives for design solutions

Once issues have been identified, package designers are skillful at generating design solutions within other types of constraints related to manufacturing, cost, packaging line and so on. The methodology is repeated until tasks are performed smoothly by the vast majority of the users.

Case study: a package containing a syringe and a vial

Background information. To demonstrate the use of the proposed method, we present a case study centering on a drug that is typically used by nurses, physicians and paramedics in emergency situations to treat severe allergic reactions, including anaphylaxis. The product was chosen based largely on anecdotal evidence of difficulty and is intended to serve as a model for demonstrating the concepts and methods presented herein.

The product consists of a folding carton (l = 48 mm, w = 26 mm, d = 142 mm) containing a plastic syringe and a glass vial filled with a liquid drug (Figure 5). Because of the short length of the glass vial, internal paperboard dividers hold it with the intention of providing its easy access when the carton is opened properly (Figure 6). As a result, the package must be opened from a specific end of the carton (Figure 5a) or the user will not have access to both (necessary) components of the drug in a context that is extremely time-critical. Tasks (and subtasks) for the intended opening include pressing two triangular flaps located on one side of the package while simultaneously grabbing the end flap and pulling it from the carton. Both scores that traverse the length dimension of the carton are perforated to facilitate the complete removal of the end flaps, exposing the contents. The opposite package's end has a glued flap that is not intended to be removed during opening (Figure 5b), and if it is, the physical divider blocks access to the product (Figure 6). The front of the package has general information about the product, whereas the back has instructions for using an aseptic technique to assemble the syringe, needle and vial.

Methodology. 1. *Identification of context/s of use*

This product is used in situations where time is critical and sometimes chaotic; typical locations include the following:

- Emergency rooms

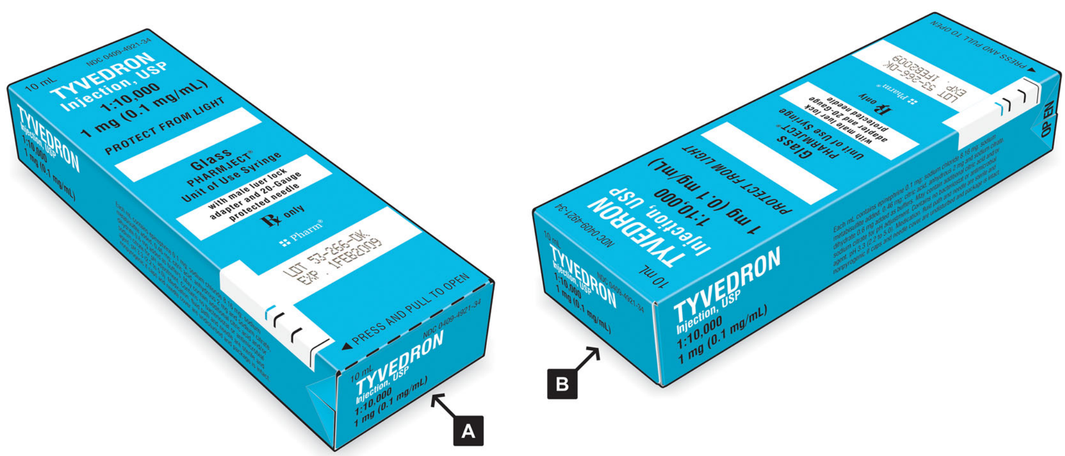

Figure 5. Folding carton containing a syringe and a vial used as case study. (a) Carton's end intended for opening and (b) opposite end with glued flaps.

DOI: 10.1002/pts

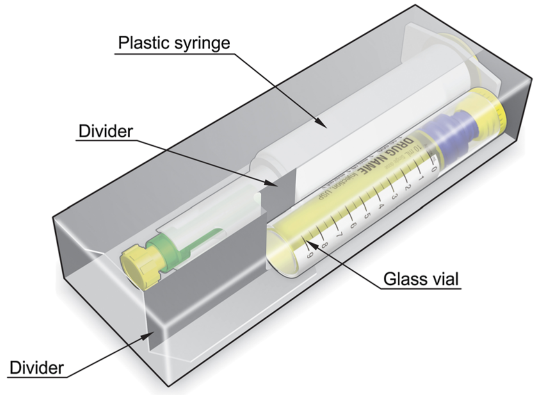

Figure 6. Internal component's layout. Notice the two vertical dividers blocking the access of the contents in one end.

- Ambulances
- Operating environments

2. *Identification of patterns of use:*
   - Emergency room: storing, opening, dispensing and disposing
   - Ambulance: storing, opening, dispensing and disposing
   - Operating environment: storing, opening, dispensing and disposing

3. *Identification of subtasks*

An ethnographic observational study in a specific context of use is performed to collect data. This data is then analysed using task analysis techniques. For example, one trial can be summarized as follows. A person first opened the package from the 'top' end (Figure 5b) by completely tearing off the glued flaps; the features delivered a false affordance regarding the appropriate end for opening. As a result, the internal dividers within the carton (Figure 6) obstructed access to the vial. Then, the person opened it from the other end by tearing apart the bottom flaps (Figure 5a). Once opened, the person got access to the contents. The second column of Table 1 details the subtasks identified (times for each task are not shown but could be included).

4. *Identification of affordances*

Each subtask identified in the previous step may be associated with an 'action possibility' or affordance (Table 1, column 3).

5. *Identification of perceptual information*

For each affordance identified in the previous step, one or more design features were associated by direct observation (Table 1, column 4). Perceptual information was identified by analysing those design features, inferred from watching user actions and fleshed with probing them with questions after completion of the tasks.

6. *Diagnostic*

User trialing showed that the product described in the previous text has a number of issues that make its use problematic. They are as follows:

- *Semantic constraint*: although the general package shape affords grabbing it, leaving only two possibilities for opening (i.e. both ends), the text orientation on the front panel may suggest to some users a vertical orientation, defining a 'top' and a 'bottom' end. When this happens, the opening feature is located on the bottom of the package; this is counterintuitive for an opening action. In general, products are opened from the top.

- *Negative affordance*: the flap on one of the ends (Figure 5b) affords opening in a place that will not allow access to the packaged drug (Figure 6). It guides the user to inappropriate opening because this end is obstructed by the internal dividers, and it is not possible to access to the contents.
- *Hidden affordances*: the actual opening mechanism (Figure 5a) is not clearly visible (*principle of visibility*). Moreover, its design feature does not clearly communicate how it functions; it does not provide good recognizable cues (*recognition-over-recall advantage).*
- *Signal-to-noise ratio:* when physical perceptual information for an affordance is not perceived, psychological information such as the arrow and the opening legends may help to communicate to the user what to do. However, the ratio of relevant to irrelevant information for opening seems compromised. Written information on this panel is lacking visual hierarchy, and as a result, the legend indicating where to open, placed at the bottom of the front panel, is not obvious.

7. *Redesign*

There are several design solutions that could be implemented to improve the package system tested. One solution is shown in Figures 7 and 8b; it uses a layout similar to the original design (Figure 8a). The redesign includes the following changes:

- Rotation of the front panel text by 180° so the package's opening mechanism is on the 'top' end (Figure 7a). This change will guide users to hold the package in the right orientation.
- Addition of folding tab that affords pulling and tearing of the top end (Figure 7a). This end keeps the original perforated feature. Written opening instructions on the front panel have been removed to avoid confusion, and the new tab has an arrow and a legend (i.e. TEAR).
- Minimization of visible edges and corners on the bottom end so it does not afford openability (Figure 7b). This change will reduce the likelihood of inappropriate opening.

USABILITY TESTING

An experiment was conducted to measure the effect of the redesigned features on opening time, a key usability measure of this particular package, and error frequency during first opening attempt.

Figure 7. Redesigned package.

DOI: 10.1002/pts

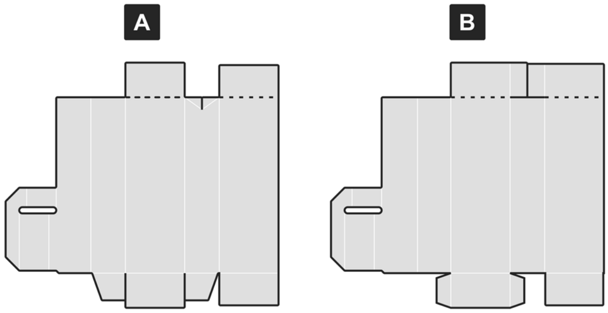

Figure 8. Comparison of the two blanks. (a) Original and (b) redesign.

Participants

Using procedures approved under IRB 13-652; r043318, a total of 26 participants were recruited at the Learning and Assessment Center on the campus of Michigan State University (East Lansing, Michigan, USA). Fifteen were men and 11 were women. Exercises in the building that day included several affiliated with emergency medicine, so a large proportion of those tested were involved in the field. All participants were older than 18 years old and self-reported no history of hand or wrist injury.

Prior to testing, participants were asked to fill in a short survey asking whether or not they were employed as a healthcare worker or student in healthcare, their area of specialization and the number of years that they had been employed in healthcare (if applicable). They were also asked whether (or not) they had personal experience with opening packages containing crash cart drugs.

Seventeen of the 26 self-identified as affiliated with healthcare (four medical students, five emergency residents, seven emergency room physicians and one administrator). Thirteen of the 17 reported that they had experience in the emergency room, but only one reported experiencing opening the packaging for crash cart drugs.

Packages

Forty-eight folding cartons (24 participants × 2 designs) were created using an illustration software (Illustrator® CS6 by Adobe®, San Jose, CA, USA) printed on white card stock (coated, 100 lb) in a production printer (Pro C651EX by Ricoh, Tokyo, Japan) and cut on a computer-controlled cutting and creasing table (Kongsberg *i*-XE1 by Esko-Graphics bvba, Ghent, Belgium). One design is labelled as 'original' package (Figure 5) and the other one as 'redesigned' package (Figure 7). Names for a fictitious pharmaceutical company (i.e. Pharm®) and a nonexistent drug (i.e. Tyvedron®) were created to make the designs more credible and realistic.

Experimental setup

Participants stood behind a counter of a fixed height (110 cm) and completed two opening tasks in healthcare facility. Two dust covers made of corrugated cardboard were placed over stimulus packages so participants could not see the packages until they were instructed to start the test. Packages were positioned under the dust covers so that text was oriented for reading in all cases. Participants were instructed to imagine an emergency scenario where they needed to remove all contents (two wooden dowels) from a package that was under each of the dust covers as quickly as possible. Time (kept with a stop watch) began when the experimenter said 'go' and ended when each of the dowels had been removed from the packages. This opening time represents the type participants took to understand the package, open it and manipulate its contents. Order of presentation was counterbalanced across designs.

Data analysis

Data were analysed using IBM SPSS® Statistics.[26] A paired-samples t test and a chi-square test of independence were computed to examine potential differences on the dependent variables related to opening time and error frequency during first opening attempt.

DOI: 10.1002/pts

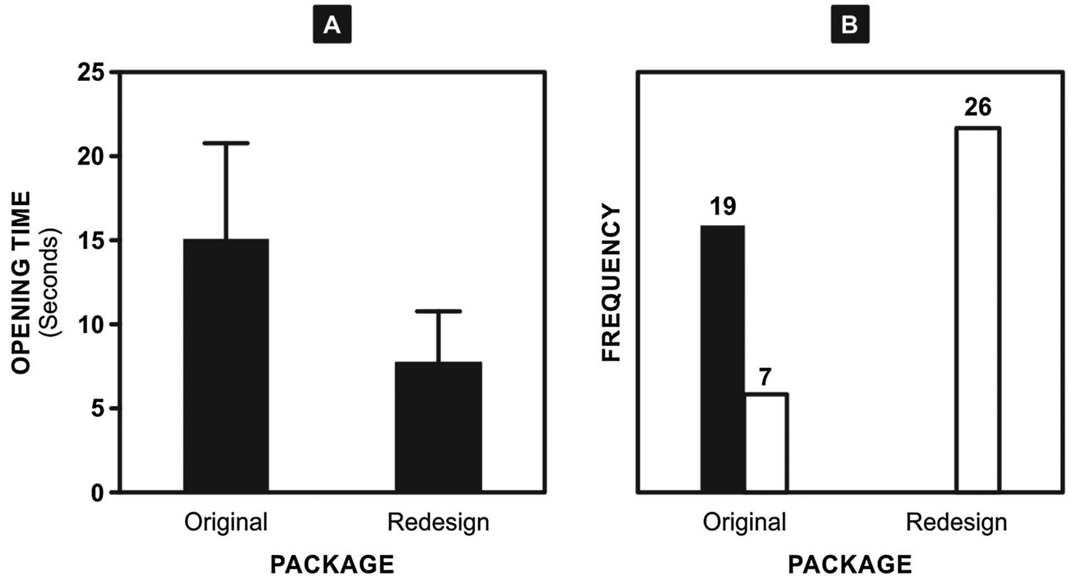

Figure 9. Usability testing results: (a) average opening times for original and redesigned packages, (b) Frequencies of opening using the incorrect (∎) and correct (□) ends for both packages.

Results and discussion

A paired-samples *t* test was calculated to compare the mean opening times for both packages. The mean opening time for the original design was 15.08 s ($sd = 5.69$ s), and the mean for the redesigned package was 7.73 s ($sd = 3.04$ s) (Figure 9a). A significant decrease of opening times from original to redesigned package was found ($t(25) = 6.46$, $p < 0.001$). This represents a drastic usability improvement for a product used under critical circumstances characterized by stress and fast pace.

The errors associated with opening also significantly differed. A chi-square test of independence was calculated comparing the frequency of 'correct' and 'incorrect' openings during the initial opening attempt for both packages. A significant interaction was found ($\chi^2(1) = 29.94$, $p < 0.0001$) (Figure 9b). People were more likely to use the incorrect end when trying to open the original package than they were when opening the redesigned package.

The original package induced 19 people to open at the top end (a false affordance); only seven people began at the 'correct' end for opening (the bottom). Four of the 19 that began with the 'incorrect end' switched to the bottom once they realized that the internal divider served as a physical barrier to removing the product. Nine of the 19 resorted to tearing the packaging in such a way that text was destroyed. The remaining people that started with the top merely tore the divider such that no text was damaged. No one dropped the product.

By contrast, the results regarding the redesigned package suggested that the design changes (text oriented intuitively to opening mechanism, a cultural constraint), and the added tear tab, a physical constraint, resulted in stronger signal strength regarding the intended affordances. All 26 participants started opening the package at the end that was intended (the top). None of the participants switched ends during opening (or opened both ends), and just a single package was torn to the point that text was damaged.

CONCLUSION

Our review of the literature regarding human-package interaction suggests a gap in the research investigating perception and cognition as it relates to packaging use. We believe that the concept of affordance can be used to produce innovations in this regard to enhance packaging functionality. This research introduces the main concepts of the theory of affordances with specific reference to packaging design applications. It presents a brief review of the affordance-based methods available and proposes a novel method for purposefully evaluating affordances related to package design. A step-by-step case study is presented to demonstrate the methodology for which a diagnostic and redesign is proposed. Usability test data supports the improvements made after using the methodology.

As current affordance-based approaches to design are cumbersome to use and focus on the design of complex products, a straightforward, affordance-based design methodology is proposed. The proposed method relates tasks, affordances and package's features for specific users and contexts of use. It is aimed to explore and evaluate package designs and provides a useful tool for package developers (i.e. marketers, designers and engineers) so that they can purposefully consider affordances during the design process to improve package usability.

LIMITATIONS

Although participants were instructed to consider the test as an emergency scenario and asked to remove the packaging contents as quickly as they could, the usability testing may not accurately represent the conditions of stress experienced by real-life users. Additionally, for consistency in testing the designs, all packages were presented with the text oriented appropriately for reading; in realistic scenarios, a more randomized presentation would be the case. It is possible that this predisposed participants to open the top end in both of the designs presented.

ACKNOWLEDGEMENTS

The authors would like to thank the Learning and Assessment Center at Michigan State University for helping with recruiting volunteers and providing a testing room. We also would like to thank the participants who took part in the usability testing.

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DOI: 10.1002/pts

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DOI: 10.1002/pts