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Designing Affordances on Embedded Interfaces

Gabriela Madalina Istan
San Jose State University

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Gabriela M. Istan

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by

Gabriela M. Istan

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Dr. Sean Laraway, Department of Psychology

Dr. Emily H. Wughalter, Department of Kinesiology

Dr. Kevin Jordan, Department of Psychology

ABSTRACT

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by Gabriela M. Istan

The purpose of this study was to examine the effects of a user interface on users' performance during an online shopping checkout task. Two interfaces were developed using the principles of Rasmussen's SRK model: a high-affordance and a low-affordance interface. Seventy undergraduate and graduate students performed a simulated online shopping task with the two interfaces. It was hypothesized that the high-affordance interface would require less time and fewer clicks to conduct the shopping task when compared to a low-affordance interface. In addition, it was predicted that participants would prefer the high-affordance interface. The findings revealed participants spent more time on the task using the high-affordance interface, but the difference was not statistically significant. Participants made significantly fewer clicks using the high-affordance interface than they did using the low-affordance interface. Compared to the low-affordance interface, a significantly higher percentage of users reported that they would prefer the high-affordance interface. This is one of the first studies to examine the application of the SRK model to the design of consumer interfaces. Based on these results, the SRK model may be considered another conceptual tool to make interfaces easier to use and consumer experiences more satisfying and enjoyable.

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Introduction

The emergence of new technologies has improved the capabilities of machines and created new scenarios in human lives. These technologies are becoming increasingly embedded in our daily lives, including touchscreen tablets, smart phones, automobile dashboards, thermostats, and automated shopping checkout systems. The properties of the computing environment are constantly changing, and these systems require complex interactions with the humans who operate them (Weiser, 1993). This poses a great challenge to the interface designers who create products to support interaction while encouraging learning and better understanding of the system in use (Hornecker, 2012).

Developing usable products in this era requires a good understanding of the relationship between the technical functionality of the systems (the environment) and user capabilities (Adolph & Berger, 2006). In this environment, people often move around and perform multiple tasks at the same time rather than sitting and focusing exclusively on the use of a single product. In addition, people manipulate digital and physical products at the same time and communicate face-to-face or remotely through digital devices. Therefore, designers need to have a good understanding of the tasks in which users are engaged and to predict the expected behaviors of users while they interact with a product (Galvao & Sato, 2005).

When technology is embedded in a space that is meant to be manipulated, the combination of real and virtual information brings a need for guidance on how to conduct the new interaction. Without this guidance, the user has difficulty performing the activity to reach a goal. The key factor for designing these products is creating interfaces that afford actions by providing cues for action, which are sometimes called *affordances*. These embedded affordances provide information that helps users expend less cognitive effort deciding how to interact with a system and ultimately learning how to perform tasks (Jacob, 2008).

The Concept of affordance

Gibson (1977) first introduced the term *affordance.* According to Gibson (1986),

> "the affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill. The verb to afford is found in the dictionary, but the noun affordance is not. I have made it up. I mean by it something that refers to the environment and the animal in a way that no existing term does. It implies the complementarity of the animal and the environment" (p. 127).

Gibson was particularly interested in how an actor detects the possibility for action of an object perceived in a specific situation. Thus, the term *affordance* refers to a one-to-one relationship between a user and an object with which he or she interacts. He suggested that organisms perceive the world not only in terms of shapes, colors, and spatial relations, but also in terms of possibilities for action using objects. Gibson developed an "interactionist view of perception and action that focused on information that is available in the environment" (Greeno, 1994, p. 336). He was particularly interested in how an actor detects, through perceptual processes, the affordances embedded in the environment in order to perform an action (Gentile, 2000). In this ecological approach, all parts of the environment afford behavior and organisms perceive these affordances, rather than merely the objects' characteristics, when performing an action. For example, a street affords locomotion by either walking or running, a surface affords support, a car affords driving, and a trail in the woods affords hiking.

Gestalt theorists influenced Gibson to hypothesize that an affordance has three features: (a) it is independent from an actor's capability to perceive it; (b) it exists relative to the action abilities of a performer; and (c) it does not change as a performer's goals and needs change. Therefore, affordances are directly perceivable (i.e., the objects in the environment are easily recognized by performers acting on them). The performers may or may not perceive an affordance, based on their current needs, but information does not change when performers change and the affordance is available to be "picked up" (Heft, 2003, p. 156). Gibson noted the "polarity of affordances" (Maier & Fadel, 2009, p. 21), in that affordances can be positive or negative. Positive affordances are favorable to the performer and have a guidance role, whereas negative affordances are potentially harmful. For example, transportation represents a positive affordance of an automobile, whereas pollution or danger to bicyclists might represent negative affordances to users. Industrial engineers and Human-Computer Interaction (HCI) practitioners should take this polarity into consideration when designing systems; they should focus on the positive affordances and avoid "harmful negative affordances" (Maier & Fadel, 2009, p. 21).

Perspectives on affordances

Perceptual view. Gibson's theory of affordances has received particular interest in the field of HCI and product design. However, the Gibsonian ecological approach for evaluating affordances relative to an actor has been considered "naive" by some that have argued that affordances are not "objective functional properties of objects" (Saffiotti & Broxvall, 2008, p. 111). Indeed, many researchers have studied affordances outside of the Gibsonian framework. Some researchers have approached affordances using an evolutionary perspective, defining affordances as properties of objects that can be explored by certain animals to meet adaptive needs (e.g., Reed, 1996). Other researchers have viewed affordances as complementary relationships between animals and the environment (Turvey, 1992). Warren (1984) further explored this approach and suggested that affordances only exist when the properties of both animals and the environment exist in the same time and same place. Warren investigated the underlying dynamics of the interaction between the actor and the environment. In a stair-climbing experiment, he allocated a measure to the concept of affordances by creating a ratio between the properties related to the environment and humans. For example, an edge would not be perceived as a step, but rather how it is associated with performers and the characteristics of their behavior (e.g., size and style of locomotion). Warren emphasized that "perception for the control of action reflects the underlying dynamics of the animal-environment system" (Warren, 1984, p. 683) and concluded that actors achieve their goals within limits of the environment.

Cognitivist view of affordances in HCI. Contrary to Warren, Norman (1988) investigated affordances of "everyday things," such as telephones and doors, and argued that an object's structure provides strong clues to its operation. Norman adapted Gibson's original concept of affordances to interface design and introduced it to technological fields. Gibson's affordances, which are directly perceived by the performer, can be contrasted with Norman's *perceived affordances*, which are "the perceived properties of things… that determine how the thing can be used" (Norman, 1988, p. 9). Norman's view emphasized both physical and mental aspects of the interaction of the performer and the environment, as affordances provide cues related to the properties of objects. Norman's cognitive approach asserted that affordances depend on the way users perceived them, based on user goals, expectations, knowledge, skills, and cultures. Norman's situational view of affordances, in which performers relate to the situations, was followed by Chemero (2003) who described affordances as "relations between the abilities of organisms and features of the environment" (Chemero, 2003, p. 189).

The exploratory nature of affordances. The cognitivist view of affordances was also followed by Gaver (1991). However, in contrast to Norman, Gaver did not consider the learning ability of the performer. Rather than focus on how the user fits the environment, and vice versa, he described how affordances support user-environment interactions. Furthermore, Gaver assessed that users explore affordances in an active, rather than passive, manner. He contributed a framework for separating affordances from information that communicates affordances (e.g., "When affordances are perceptible, they offer a direct link between perception and action; hidden, and false affordances lead to mistakes", p. 79). Gaver also introduced the ideas of "sequential affordances" and "nested affordances." He defined sequential affordances as actions on perceptible affordances that lead to the discovery of other affordances (Gaver, 1991,

p. 82). His example of sequential affordance, "grabbing" an on-screen object leads to "dragging" it to the graphical representation of a recycle bin, is still widely used in the HCI literature. In contrast to sequential affordances, the "nested affordances describe affordances that are grouped together" (Gaver, 1991, p. 82) and imply a combination of individual affordances into a new affordance. For example, a smart phone provides an affordance of communication through a combination of other properties (affordances): a touch screen that can be pressed to access the device and receive wireless support. Gaver's exploration of the system to discover affordances introduced the idea that some affordances may be discovered by a performer to act on, while others may not be discovered. What separates these is the goal direction of a performer (Stoffregen, 2003). When a performer conducts an action to achieve a particular goal, he or she acts on the affordances that correspond to that specific goal, while ignoring others.

Hierarchical nature of affordances. McGenere and Ho (2000) explored the hierarchical nature of affordances and suggested that "the affordances exist… in a hierarchy and the levels of hierarchy may or may not map to system functions" (p. 7). Furthermore, affordances should be considered from two perspectives: "the ease" with which a user may perceive an affordance and the "clarity" of the information the affordance carries.

Hartson (2003) discussed the stages of an action and identified four types of affordances: cognitive, physical, sensory and functional. He asserted that each type of affordance represents a different role in the performer-environment interaction. The cognitive type relates to Norman's perceived affordances and it is related to semantics in a way that helps the performer to know about a feature. The scientist defines "cognitive affordances" as "something to help the user in knowing (e.g., knowing what to click on). We see symbols, constraints, and conventions as essential underlying mechanisms that make cognitive affordances work" (Hartson, 2003, p. 319). As an example, a label on a button represents a cognitive affordance because it enables users understand the functionality of the button and consequences of action on it. For example, when interacting with the "Edit" button on iPhone, users knows that, when tapping on it, the button will facilitate e-mails grouping in different categories. Therefore, the semantic meaning of a product's feature is cognitively formulated based on the information the performer receives from the environment.

Physical affordances correlate to what Normal called "real affordances" and they are associated with "operability" (Hartson, 2003, p. 322) because they help users to conduct a physical activity. The size and location of a button on a screen represent physical affordances because they enable users to easily interact with the button. The "Edit" button on the iPhone can be located in the right corner in the e-mail account so users can tap on it easily and accurately.

Hartson (2003) also introduced a new type of affordances in the HCI field: *sensory affordances*, which he defined as properties of the stimuli the actor perceives. Sensory affordances help performers with their actions and accentuate characteristics in the design related to the sensations (haptic/tactile, visual, or auditory). Thus, sensory affordances play a support role for the first two types of affordances (i.e., cognitive and physical). "Sensing cognitive affordances is essential for their (users) understanding, and sensing physical affordances is essential for acting upon them" (Hartson, p. 322). For example, the shape, the color and size of a button are all properties that make the button more noticeable and help the user to focus his or her attention to that button.

The forth type of affordance, the functional affordance, is "a design feature that helps a user accomplish work, i.e. the usefulness of a system function" (Hartson, 2003, p. 323). This type of affordance relates to the functionality of a feature and gives users "access to a certain application feature or functionality" (Hartson, 2003, p. 323). By tapping on the "Edit" button on an iPhone, for example, users have access to a specific functionality of the device, such as categorizing e-mails in groups.

Application of Gibson's affordances in designing interfaces

The concept of affordance was advanced in the HCI field to improve the usability of interfaces. Norman (1988) introduced the concept to accentuate the necessity of designing properties that would make interfaces easy to use. "When affordances are taken advantage of, the user knows what to do just by looking: no picture, label or instruction is required" (Norman, 1988, p. 9). However, as noted earlier, Gibson's concept focused on the perceptual side only, leaving the activity of the organism out of the equation, which lead to misunderstanding of the concept (Bærentsen, 2002). Because affordance is a relationship between organism and environment, the perception of affordances is a perception of the relations between the body of the performer and the environment in which the activity takes place. Thus, an affordance is perceived based on two types of information: "about the environment (exteroception) and the organism (proprioception) taken together" (Bærentsen, 2002, p. 53). Furthermore, the direct perception of affordances in the HCI environment is almost non-existent, because "most aspects of the relevant affordances do not have an exclusively evolutionary biological explanation" (Bærentsen, 2002, p. 53). Two perspectives in HCI discussed in this literature review were meant to overcome this shortcoming by including the concept of activity: the Activity Theory (AT) and the Ecological Interface Design (EID).

An activity model of affordances

Contrary to Norman and Gaver's cognitivist approach on affordances, AT (Leont'ev, 1978) proposed an approach that emphasizes the importance of goals, purposeful activities, and personal development. This approach illustrates that human activity must be examined in different contexts. Leont'ev explained that affordances are not "static" concepts that exist out in the environment waiting for a performer to detect them. Human learning is goal-directed, so affordances are only affordances as long as they are understood within performer's development. Thus, AT includes a framework that describes three dynamic components: activity motive (WHY), action goal (WHAT) and operation conditions (HOW). Therefore, affordances represent features of an activity system consciously perceived through human knowledge (Leont'ev, 1978). From this perspective, Gibson's approach focused exclusively on the perception of the operational conditions of the environment (HOW) that guides locomotion, leaving the motive (WHY) and the goal of the activity (WHAT) out of the equation.

From the traditional cognitive point of view, the HCI system is "an information processing loop" (Kaptelini, 1993, p. 54) with two components: the human actor and the computer. The output of one component enters into the other one's input and vice versa.

This traditional cognitive framework is a closed model that does not take into consideration what is happening outside of the loop. On the contrary, from the AT perspective, the computer represents a tool that moderates an activity between human actors and the environment (Kaptelinin, 1993). Furthermore, affordances are not isolated properties of artifacts; affordances represent properties of objects that relate to activities. When, for example, a person grasps an object, this type of an affordance ("graspable") relates to one level of the activity, the operational level. The other two levels mentioned in the framework, the motivational and the goal-oriented levels, make an activity meaningful in a biological and social sense (Bærentsen, 2000).

The immediate applicability of the AT framework in HCI is in designing related affordances at the motivational level (related to the function of the system), instrumental affordances (at the goal-oriented level), and operational affordances (at the operational level). In order to touch these three components of the framework, an interface must advance a "minimal understanding of its affordances (i.e. the function it affords)" (Bærentsen, 2000, p. 32), in other words, it must be "intuitive" (Bærentsen, 2000, p. 32). The WHY-WHAT-HOW framework aligns with the assumption that performers have goals and intentions. Thus Bærentsen's approach can be considered a leap from Gibson's original work (perception) to interpretation.

The AT model was continued by Vicente (1992), who proposed the Ecological Interface Design (EID) approach in which the relation between the performer and the environment is described as a dynamic world model.

> “The framework… is based on the skills, rules, knowledge taxonomy of cognitive control. The basic goal of EID is twofold: first, not to force processing at a higher level than the demands of the task require, and second, to support each of the three levels of cognitive control” (Vicente, 1992, p. 589).

Previous theories in HCI have explored different levels of affordances (Hartson, 2003; McGenere & Ho, 2000), but have imposed limitations on designing the embedded systems because they fail in providing an explanation of how affordances cognitively function. The technology is perceived from two perspectives: the object on which the user will perform the action and the performer’s perception-action system (Heft, 2003). This poses a challenge to the designers who need to understand users’ actions and embed affordances within interfaces accordingly.

The deep structure of affordances – the SRK model

To address this challenge, Vicente and Rasmussen (1992) explored a deeper structure of affordances and created a model that supports the understanding of how performers actually explore interfaces and learn their functionality in the long run. Based on participant observations and interviews, these authors identified a number of repeated events and properties of the environment in which the work took place and compared them to Gibson’s concept of affordances. Gibson assessed that information pickup is a direct action, but, according to Rasmussen (1983), the relationship between a performer and an environment is mediated:

> "At a higher level of conscious planning, most human activity depends upon a rather complex sequence of activities, and feedback correction during the course of behavior from mismatch between goal and final outcome will therefore be too inefficient, since in many cases it would lead to a strategy of blind search. Human activity in a familiar environment will not be goal-controlled; rather it will be oriented towards the goal and controlled by a set of rules which has proven successful previously" (p. 258).

Thus, performers can reach the goal of the action through a better performance when they are provided with the highest level of possibilities and dynamically directed to these alternatives through affordances or "cues for action" (Rasmussen & Vicente, 1989, p. 524). Furthermore, the way the actor perceives the functional properties of a system depends on the individual's goals and intentions. The same approach, previously discussed, relates to Gaver's goal-oriented or functional affordances. To further explain his theory, Rasmussen classified affordances using three categories ("why, what, and how") based on two concepts: the abstraction hierarchy (I) and the Skills-Rules-Knowledge (SRK) model (II).

Abstraction hierarchy (I). Vicente and Rasmussen (1992) asserted that the environment carries multiple action possibilities, and the abstraction hierarchy identifies functions to guide the performer to choose the right action needed for reaching the goal. For example, a touch screen interface affords motion-enhanced touch (WHAT) by touching (HOW) to achieve a goal of pleasure or safety (WHY). These three questions represent different views a performer might have of the environment. Thus, the abstraction hierarchy implies multiple levels of an action that range from low level (physical properties that can be found by answering the questions WHAT and HOW) to high-level properties (answering the question WHY). The answers to these three questions describe the correlation between the levels of the hierarchy and affordances. The low-level properties can be related to Hartson's physical and sensory affordances, whereas the high-level properties relate to cognitive and functional affordances (Laarni, Norros & Hoskinen, 2007). This model dynamically connects performers to actions that are more suitable for a specific goal. Thus, the interface supports the performer's cognitive control, and, thus, the performer can better explore the system as it is, with fewer constraints. One immediate application of these concepts in the field of HCI is in the creation of clear interfaces that facilitate motor learning.

Skills-Rules-Knowledge model (II). In many systems, actors must interpret the information perceived in the environment with which they are interacting and transform the information into action (Wickens, 2000). The second component of Rasmussen's model, the Skill-Rules-Knowledge (SRK) taxonomy, represents a framework for describing how actors interpret the information in the environment in order to perform actions. The SRK model was first introduced to illustrate how humans can perform activities and intervene in machine operations, when required, in high-risk domains, such as power-plant control. The SRK model is a dynamical model that leads performers to alternative options they can choose based on a specific problem and "support … exploration of systems without imposing normative constraints for navigation"

(Albrechtsen et. al, 2001, p. 24). The model also entails a learning dimension by presenting a variety of options performers can analyze before action on one of the options takes place.

Rasmussen introduced the SRK framework in the context of information processing theory. The purpose of this model is to explain how actors gather and understand the information presented on an interface in order to perform a work activity. Furthermore, because it describes different performance patterns suitable for both familiar and unfamiliar situations, the framework is often adopted to reduce the complexity of performers' cognitive processes. Rasmussen described three categories of performance: signal- (SKILLS), sign- (RULES) and symbol-based (KNOWLEDGE) performance. According to this model, people act on one of the three levels based on the nature of the task and their experience with the situation.

The Skill-based behavior is characterized by routine activities that do not require conscious attention or control. This type of performance implies a high degree of automaticity when a person performs an action. Moreover, the level of automaticity when conducting the task is determined by the performer's level of practice. Thus, highly experienced people operate at this level as it involves automatic processing. "At the most automated level, the Skill-based behavior assigns stimuli to responses in a rapid automatic mode with a minimum investment of resources" (Wickens, 2000, p. 337). At this level, actors do not consciously detect sensory input and perform the behavior based on stored schema of procedures in their behavioral repertoires. However, in interactions with complex systems, the rapid action happens only after the performer receives training and becomes an experienced performer; in Rasmussen's words: "the man looks rather than sees" (Rasmussen, 1986, p. 101). In Gibsonian terms, in a situation that involves this type of behavior, "the actor perceives and acts directly in mutuality with the environment" (Albrechtsen, et al., 2001, p. 22). Rasmussen included one more layer of an internal "dynamic world model" that the performer unconsciously and constantly updates to adapt the skill to different situations.

The Rule-based behavior is more conscious, and the action is selected by "bringing to working memory a hierarchy of rules: If X occurs, then do Y" (Wickens, 2000, p. 338). When the actor handles familiar situations, his or her action is guided by known rules that have been learned from previous experiences. The performer mentally browses these previously stored rules and compares them with the stimulus. Then the performer makes the appropriate decision followed by the appropriate action. This type of behavior occurs when people are familiar with tasks but do not have extensive experience with them. The cues in the environment activate the rules acquired from past experiences, and the performer then applies a learned pattern of performance. The actor bases his or her behavior on solutions and decisions previously learned and successfully used in the past to conduct the task. When the state of the system is displayed through various sensory cues, performer acts on those cues without applying extra cognitive resources.

When the action to perform is entirely novel, analytical processing is required and the actor operates at the Knowledge-based level. The actor cannot use rules or "automatic mappings" (Wickens, 2000, p. 338), because they are not available from previous experiences. At the Knowledge-based level, behavior is controlled by goals and it can only be animated when "relational structures of information are available" (Albrechtsen et al., 2001, p. 23). This type of behavior occurs in completely unfamiliar situations, and the actor uses his or her knowledge about the system's behavior, the system's characteristics, and the actor's goal when interacting with this system to create a novel plan of action. When creating the plan of action, the actor relies on analytical processes and applies stored knowledge in decision-making. These processes result in high mental workload. However, practice can reduce the mental workload by transforming unfamiliar situations into familiar situations that require the activation of the rule-based performance level. Furthermore, extensive training can transform the knowledge into automatic responses (i.e., into Skill-based performance).

When the work domain is dynamic and complex, performers confront a variety of unfamiliar situations that require the activation of the Knowledge-level behavior. Experts in familiar situations will use the Rule-based behavior. The three types of behaviors are "complementary and they are all necessary to fulfill actors' goals" (Albrechtsen et al., 2001, p. 23). In the real world, a person can perform at any of the three levels and change them depending on task familiarity and expertise. According to Rasmussen (1986), most tasks will require all three types of behavior and a "dynamic world model" mediates the shift between them:

> "A kind of dynamic world model is necessary to account for control of responses to the environment that are too fast to allow control by simple perceptual feedback. Often-cited examples are fast sequences in sport,

musical performance, etc. … To serve this purpose, it is necessary that the internal dynamic world model simulates not only the behavior of the environment, but also of the body; i.e. it stimulates the interaction" (p. 80).

Rasmussen's model can be applied in situations that involve both the environment and the actor. Thus, in order to better understand human performance, Rasmussen addressed the Gibsonian principle of *mutuality*, and introduced one more layer between the two components of the action. In Gibson's terms, actors directly pick up information from the environment with no mediation needed. However, in Rasmussen's terms, the relation between the actor and environment is always mediated. The actor's dynamic world model allows him or her to switch between the Skill-, Rule-, and Knowledge-based behavior levels, and the activation of one of these types of behavior will depend on the form in which the information is presented and interpreted by actors: as signals (skills), sign (rules), and symbols (knowledge).

Rasmussen's model has a direct applicability in environments in which complex operations are performed. Rasmussen (1986) not only described the environment and the actions most suitable to specific environments, but he also outlined sequences of the actions to be performed by an actor while interacting with the interface: (a) an event happens in the system; (b) the performer observes the event; (c) the performer diagnoses the current condition of the system; (d) the performer evaluates the consequences for the both the system and operator; (e) the performer evaluates the ambiguity; (f) the performer determines the tasks required to respond to the event; and (g) the performer formulates procedures and rules that need to be followed when executing operations.

Perceptual affordances in Human-Machine Interaction

Rasmussen and Vicente (1989) proposed their model to resolve the issue of designing interfaces that would allow a performer to investigate a system's interface without "normative constraints… as in the direct manipulation interfaces" (Albrechtsen et al., 2001, p. 24). Researchers also have explored the applicability of Gibson's perceptual approach on affordances in highly cognitively demanding work domains. Thus, Rasmussen's SRK framework outlines the challenges the system designers must face. Unpredictable events can happen; thus, it is crucial that designers have a good understanding of human information processing and the environment in which the actor will perform. Furthermore, the model helps identify which part of the task can be automated and which part can or must be supported because it includes both the bottom-up and top-down processing. The Skill- and Rule-based behaviors respond directly to stimuli in the environment, so perception followed by a sequence of action is required, whereas the Knowledge-based behavior requires activation of the performer's knowledge and problem-solving skills (Vicente & Rasmussen, 1992). Thus, the model supports both the perceptual level of affordances and performer's cognitive control, depending on the actor's capabilities and expertise level and the features of the environment.

Expert affordances come with practice

Actors can acquire expertise by the cognitive control of the information that exists in the environment, which affords different properties that guide performers in conducting routine actions. However, this connection is not spontaneous, but results from extensive training. Learning is strongly related to the information available in the environment and “interpretable in a performance instance” (Guadagnoli & Lee, 2004, p. 213). Thus, learning can only occur in the presence of information, and the amount of information needed depends on performer’s skill level, as well as the “functional difficulty of the task” (Guadagnoli & Lee, 2004, p. 213). The potential of available information increases as the difficulty of the task increases. However, there is a limit to a performer’s understanding of this information, which depends on performer’s information processing capabilities, which can improve with practice (Marteniuk, 1976). This limit imposes an optimal amount of potential information to be processed, “the optimal challenge point,” as described by Guadagnoli and Lee (2004, p. 216). As the difficulty of the task increases, so does the amount of information the actor must process to perform the task. However, when the amount of information exceeds the actor’s processing capabilities, the optimal challenge point has passed and the potential learning benefit decreases.

Implications for interface design

The SRK framework helps designers understand how to embed the right affordances for every sequence of action. The ultimate goal of designing the right type of affordance is to help the performer conduct the entire action step-by-step with the least amount of cognitive effort (Rasmussen & Vicente, 1989) and the fewest number of errors (Wickens, 2000). Physical affordances, that sustain direct interaction, can be applied to digital or physical objects. Sensory affordances provide auditory (pitch, timbre), visual (color, depth, shape), and physical feedback (movement, tactile information). Cognitive and functional affordances provide performers with information needed in order to conduct cognitive activities.

"Making visible the invisible" (Rasmussen, 1989). The goal of EID is to create interfaces that will command low levels of cognitive control and provide support for each of the three levels of behavior (Skill-, Rule-, and Knowledge-based). Therefore, the objective of designing interfaces based on the SRK model is to encourage the performer to make use of the Skill- and Rule-based behavior (to ensure the conservation of limited cognitive resources), while "providing support for otherwise more effortful and error-prone Knowledge-based behavior" (Vicente, 2002, p. 64). Consequently, the performer can use these cognitive resources for unfamiliar situations that require problem solving.

Each of the three levels of the SRK taxonomy is supported by the following design principles. First, users should be able to perform directly on the interface (Skill-based behavior), and "the display of information should be isomorphic to the part-whole structure of movements rather than being based on an abstract, combinatorial code like that of command languages" (Rasmussen & Vicente, 1989, p. 528). In other words, the visual features of the interface should support sequential, logical movements that allow the actor to grasp the whole as a whole, in which the meaning of one individual button, for example, is derived from its relationship to the whole. Second, there should be a consistent mapping between the performer's conceptual model and the interface's constraints, such as signs or cues for action (i.e., Rule-based behavior). Third, the interface should be presented in a "form of an abstraction hierarchy" that assists the performer by presenting the information that can be interpreted in different ways through reasoning.

Various studies have attributed the benefit of providing the user with higher-order functional information that supports problem solving. For example, in the context of thermal hydraulic process control, Pawlak and Vicente (1996) compared an interface based on EID that contained both physical and functional information with a conventional interface that contained physical information only. The EID interface resulted in better performance in terms of faster detection and more accurate diagnosis. Furthermore, the EID interface produced a “functionally organized knowledge base” (Vicente, 2002, p. 65), but only if participants received and acknowledged proper feedback from the interface.

Sharp and Helmicki (1998) compared an EID interface (which provided both functional and physical information in a graphical form) with a conventional interface (which presented physical information in an alphanumeric format) in a neonatal care unit. The participants were recruited based on three levels of expertise and asked to detect severe clinical situations. Overall, the EID interface led to the best performance. The least experienced group of participants achieved better performance with the EID interface, but the interface did not have a significant effect for experienced participants. The researchers attributed the results of the study to the fact that experienced group had more experience with the low-affordance interface. However, the results showed an overall better performance on the EID interface.

Xu, Dainoff, and Mark (1999) analyzed an EID interface on three tasks involving information retrieval: a problem-solving task (requiring participants to inspect the entire database to solve a problem), a complex search (requiring participants to explore and find various facts), and a simple search (requiring participants to find one single issue in the database). Xu et al. found that participants had significantly faster search times and less disorientation when conducting both the problem-solving and complex tasks but not when conducting the simple task.

Concepts beyond affordances

Lu and Cheng (2012) suggested a new framework in HCI and proposed a distinction between the "information about affordances and affordance itself" (p. 4). An object can have multiple properties, but people usually perceive the typical function of that object: "For example, if the probability of affordance A of an object is 80%, it means that 80% of the population can perceive the affordance" (p. 4). To further illustrate this, the authors gave an example of a pen, which obviously affords writing, but can also be used as a weapon in a dangerous situation. This concept, which is about the affordance itself, is called the "perceptual probability of affordance" (p. 5). However, because different people have different approaches when detecting the same affordance of an object, Lu and Cheng described the concept of "perceptual threshold of affordance," which is a "the threshold at which affordance can be perceived by an individual" (p. 5). The implication of Lu and Cheng's framework on designing affordances is that the designer must accentuate positive affordances by reducing their perceptual thresholds and suppress the negative affordances by increasing their perceptual thresholds.

Simple and complex affordances. Gibson's affordances are directly perceivable by the performer; thus, the performer acting on an object in the environment directly recognizes the meaning of that object. Turner (2005) categorized these types of affordances as "simple affordances" and gave an example of the design of the physical volume knob: "rotating a knob clockwise afforded increasing the volume… likewise an anticlockwise direction signified a… reduction" (p. 3). In contrast to simple affordances, Turner described complex affordances as those that depend on the specific capabilities of the actor who internally creates the meaning of the object by further information processing. Complex affordances encompass practice and history. An example of a complex affordance is a technical system that provides remote communication. When participants join in a video conference call, they have a variety of affordances that support actions they can use to communicate, such as joining in a shared space, pointing at something, monitoring other people's signs.

Learning affordances. With respect to learning, one question is when exactly an affordance appears as such to the novice performer. Gibson's theory was often criticized for his emphasis on the affordance of a mailbox, which can be directly perceived (Bærentsen, 2002). However, some have argued that perceiving a box as a place to store and retrieve mail depends upon previous knowledge that we can only acquire through learning rather than through direct perception. Thus, we learn affordances, which are "developed as adaptations of sensorium and perceptual systems to invariants in flow/form/time patterns in the ambient sensory array" (Turvey & Carello, 1986, p. 154). To further illustrate how affordances are learned, Warren (1984) showed that, for actors to step or jump over an obstacle, they have to learn the relative size of their body and limbs and compare them to the size of the obstacle. Moreover, the organism must have the motivation to move over the obstacle (e.g., to obtain food, avoid a predator). For the action to be repeated, the organism must experience the consequences that satisfy the original motive. The way performers learn an affordance often involves exploring the environment and positioning themselves in the environment. The affordance of "passibility," for example, is learned through practice.

Humans learn how to use object affordances during their lives, either by exploration of the world or through social interaction (Montesano et. al, 2008). Small children interact with objects and learn how to use them to conduct more complex tasks. Thus, affordances are exposed to us gradually or suddenly, depending on individuals' different physical and mental capabilities, as well as the level of enrichment of their environment. Van der Kamp, Oudejans, and Savelsbergh (2003) examined humans' capabilities to manipulate and noted that actors learn every time they interact with the environment. However, the amount of learning depends on the existing repertoire of the performer. A novice first must determine the actions that he or she needs to take to find the proper correlation between the movement and information. In contrast, experts have acquired knowledge of the affordances through practice; thus, they spend less time conducting the task. With practice, affordances that were difficult to recognize become easily recognizable.

Learning affordances involves learning relations between motor abilities and perceptual skills (Adolph, 2006). With training, affordances that were once difficult to recognize become easily recognizable and humans can become skilled perceivers, such that they quickly recognize what behaviors a situation affords. In robotics, affordances have been mainly used to relate actions to objects (Montesano, Lopes, Melo, Bernardino, & Santos-Victor, 2008). In a developmental experiment with the robot Baltazar, Montesano et al. examined how the robot acquired skills gradually. Like newborns, Baltazar started with a core set of capabilities, which "through self-experimentation and interaction with the environment and other humans, would progressively lead to the acquisition of new skills" (p. 16). Montesano et al. showed that robots can learn motor controllers through experimentation, and, once robots have this information, they start to set up relationships with objects through objects' features.

Summary

This literature review focused on the concept and usage of the concept of *affordance* as it was first defined by Gibson (1979). Different contemporary perspectives on the functionality of affordances were then presented. Applied science uses affordances in HCI and robotics, but these areas are always changing, bringing new scenarios to people's lives. Everyday experiences afford people new opportunities to interact with objects, and through practice people learn how to associate the object and perceived outcome in order to conduct an action.

Technology affordances are powerful tools for operating the interfaces and embedded systems are designed to reflect how these affordances can support a performer's reflections on the outcomes of his actions. Technology affordances are not simply representations of various widgets on a screen, but are also properties of the human-environment system. Affordances depend on the specific capabilities of the performer. Therefore, the biggest challenge for designers of new interfaces is to determine what information on the screen will afford humans with interaction, given their cognitive and perceptual abilities and motives. A challenge for systems designers is to embed affordances that support users' action possibilities, making these technologies intuitive, user-friendly, and easy-to-use (Bærentsen, 2002). A designer should consider what kinds of affordances to make available to a user based on the user's level of cognitive control (or effort) during interaction with the technology in question. Therefore, the ultimate goal of designing the right type of affordance is to help the users perform an action of interest with the least amount of cognitive effort (Rasmussen & Vicente, 1989, p. 527) and the smallest number of errors possible (Wickens, 2000, p. 338).

Technologies change quickly, and people need routines for repetitive actions. When the routines lead to achieving the desired outcome (performing a successful action), they are reinforced and automatized. When they fail, a complex problem-solving activity is required and performers switch from automatic behavior to Knowledge-based performances. Much of the research conducted so far on the application of Rasmussen's SRK model of behavior has focused on complex systems in highly demanding cognitive environments (e.g., hospitals, cockpits, nuclear plants). Most studies conducted from a cognitive engineering perspective within this theoretical framework have examined more error-prone work domains that require "worker adaptation to change and novelty" such as manufacturing (Vicente, 2002, p. 62). Nevertheless, it is believed that the SRK model may benefit designers of interfaces for consumer products used in everyday environments. This literature review revealed a lack of empirical studies in the HCI field with regards to the application of the SRK model to designing embedded interfaces in such products.

To this researcher's knowledge, designers have not used Rasmussen's SRK model to design interfaces for normal consumer situations. Therefore, it is not clear the extent to which this model can be applied to simpler situations that have previously been studied using the SRK model. Consequently, research is needed to determine the extent to which the SRK model is useful for designing interfaces for consumer devices. The purpose of the present study was to explore the application of the SRK model to a simple consumer activity: online shopping. The purpose of this research was to demonstrate that the SRK model provides interface designers with another conceptual tool to make interfaces easier to use, thereby making the consumer experience more satisfying and enjoyable. To do so, two interfaces were compared. One, the high-affordance interface (HAI), was based on the SRK model. That is, the HAI was meant to provide affordances that would only require users to engage in Skill- or Rule-based behavior. The second interface, the low-affordance interface (LAI), did not provide these affordances. Two aspects of performance on these two interfaces (amount of time and number of clicks) were measured while participants completed a simulated online shopping task. The rationale for these two measures comes from Wickens (2000):

> "In decision making and diagnosis, more characteristic of rule- and knowledge-based behavior, accuracy is the most important measure of

performance. Whereas accuracy is quite high in these tasks, the response time is considered to be the critical measure of performance quality of a person interacting with a system. The skill-based actions are understood through the study of reaction time" (p. 338).

Participants' reported preferences for one of the two interfaces after completing the tasks was also measured. Strong empirical evidence suggests that people have a definite preference for lower levels of cognitive control, even when the interface is not designed to support this type of behavior (Vicente & Rasmussen, 1992). Therefore, the HAI should have required less cognitive control than the LAI.

In conducting this study, it has been assumed that the LAI lacked sufficient affordances and, therefore, required Knowledge-level behavior from users to perform the task. In other words, participants must have used problem-solving skills to complete the task because the interface did not provide effective affordances that allow Skill- or Rule-based behavior. The purpose of the study was to determine how interface (high- or low-affordance) affects performance and user preference.

Research hypotheses:

1. The HAI would require less time to complete the task than would the LAI.
2. The HAI would require fewer clicks to conduct the tasks, indicating more efficient performance.
3. A higher percentage of participants would choose the HAI over the LAI for future use.

Method

Participants

After obtaining approval from the San José State University (SJSU) Institutional Review Board (see Appendix A), 70 students attending SJSU were recruited from three lower-division psychology classes (n = 22, 31.4%) and one graduate-level human factors class (n = 48, 68.6%). Students received course credit for their participation. All participants completed a demographic questionnaire to record their gender, age, college grade level, ethnicity, Internet use, and the frequency of online shopping (see Appendix B). Participant ages ranged between 18 and 61 years, with an average age of 26.6 years. Participants were 36 males (51.4%) and 34 females (48.6%). With regards to their ethnicity, 12.9% of participants were Hispanic, 32.9% were White, 42.9% were Asian, 7.1% were Black/African American, and 1.4% were other Pacific Islander. The sample was fairly representative of the San José State University student population with regard to gender and race/ethnicity.

Participants spent between 2 and 120 h per week using the Internet (M = 33.84, SD = 24.31). If participants provided a range of hours (e.g., between 2 and 4 h), the mean duration was calculated and included in the analysis. If participants provided the least number of hours they spent on the Internet (e.g., 20 h or more), the minimum number of hours was taken into consideration. Two non-numerical descriptions were removed from the final data (“A lot”, “I don’t know”).

As shown on Figure 1, participants rated their online shopping experience as follows: (a) 3 participants (4%) chose almost never (defined as about once in every six months); (b) 10 participants (14%) chose rarely (about once every two months); (c) 36 participants (51%) chose sometimes (about once a month); (d) 20 participants (28%) chose often (about once a week); and (e) 1 participant (1%) chose very often (about once a day).

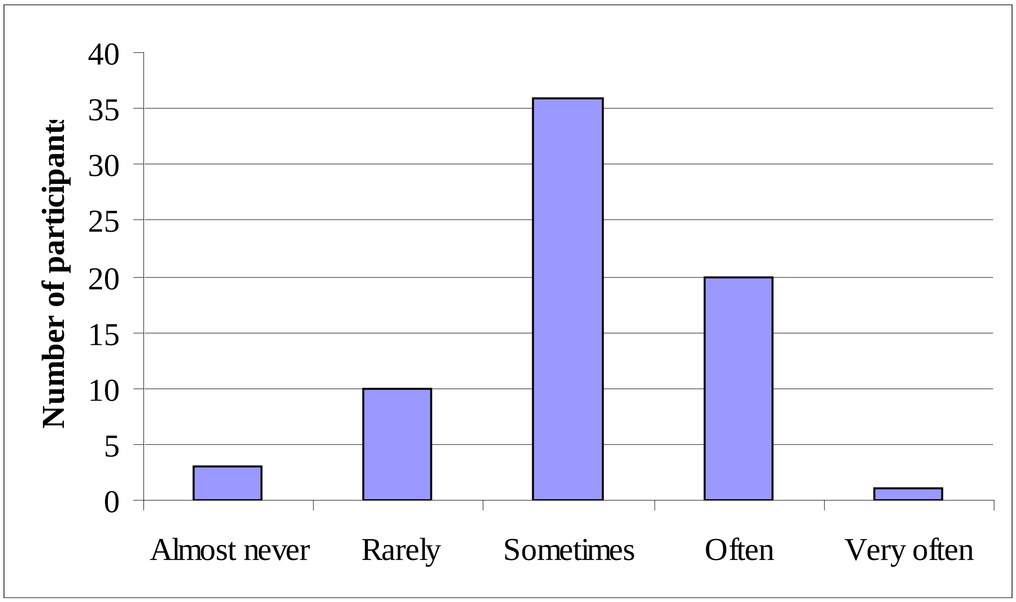

Figure 1. Participant online shopping frequency.

Setting and Apparatus

The study was conducted in a computer laboratory on the campus of SJSU. The laboratory was equipped with 20 i7 PC workstations. Twenty students were tested in one session. Each student station had a PC – Dell Optiplex 990 running the Microsoft Windows 7 Professional (64-bit) operating system. All computers had Internet access. The computer equipment consisted of a PC, a standard Dell keyboard, a 1600 x 900 resolution monitor, and a mouse input device to complete the tasks. Participants were seated 20 in from the monitor parallel with the screen.

Materials

Prototyping tool. The interactive wireframe software Axure RP Pro 6.5 was used to create the web interfaces. The prototypes were generated into active HTML website wireframes that were uploaded in the online software tool used to collect data described below.

Software tool. The task-based study was created using the Online Research Software tool UserZoom. This tool allowed the researcher to create, edit, launch, monitor, and collect data when participants performed each task. To create the online study, the researcher started with the Welcome page, which contained the tile and a short description of the study, followed by the Instructions page. Three tasks were created within the study, and the first two tasks were followed by post-tasks questions. A more detailed discussion of the interfaces and tasks will be presented in the Procedure section below. The study ended with the demographic questionnaire and a short preference survey.

While creating the study, a HTML file of the Axure prototype was uploaded for each task on the UserZoom website. When the project on UserZoom was launched, a link to the online study was automatically created and uploaded in the Firefox browser on each computer in the lab. This procedure was preferred over the option to send the link through an e-mail to each participant in the study, in order to have participants start the study immediately after they sat at the computer station.

Procedures and Study Design

In this study, two types of interfaces were tested. The first interface contained affordances and information meant to ease the task by applying the Skill-based and Rule-based performances. This interface was called the *high-affordance interface* (*HAI*), termed *Interface X* for participants (see Appendix C). This interface had more predominantly salient features and controls to guide navigation and ease the flow of the task, including Skill-level elements (light blue hyperlinks, color fill behind text and shadow to give the object depth that gives the affordance of a clickable button, shopping cart symbol), and Rule-level elements of a goal-oriented design (search bar at the top of the page, more options at the checkout for shipping).

The second interface contained less information and required Knowledge-based level processing, which implies additional cognitive work from participants in order to successfully perform the task. This interface was called the *low-affordance interface* (*LAI*), termed *Interface Y* for the participants (see Appendix D). This interface included simple text instead of colored buttons (e.g., “checkout” or “add to cart”) and limited options with regards to the shipping method as well as a search bar at the bottom of the screen. Therefore, it had fewer affordances, so the user would have to use the Knowledge-level behavior in order to process the information presented on the screen.

After participants were asked to turn off their cell phones and not to talk to each other, they were verbally presented with general instructions of the study. As they started their interaction with the UserZoom website, participants were informed about the scope of the study in the Welcome page and received specific instructions with regards to how to perform the task using UserZoom in the Instructions page. Before proceeding to the first task, participants were presented with a digital version of the consent form (see Appendix E) and informed that, by clicking on the “Next” button, they agreed to participate in the study.

Participants conducted the first two tasks on a PC, using both interfaces in a random order. When performing these tasks, participants had a smaller window opened all the time at the bottom of the screen, containing a short description of the task and two buttons (Success and Abandon; see Appendix F). They could choose either one of the buttons based on their performance on task: *success*, if they completed the task, or *abandon*, if they were not able to finish it. In the first task, participants were asked to find and purchase a book written by Michael Pollan, *The Omnivore’s Dilemma*, using the HAI. They were informed that some text fields were pre-populated and they did not have to enter the normally required data (e.g., credit card information, shipping address). After interacting with the HAI, participants were asked to fill out a short post-task questionnaire. The questions used a five-point scale, from 1 being very difficult to 5 being very easy (for the question on easiness of the interface), from 1 being not successful to 5 being successful (for the question on rating their own performance on the interface) and from 1 being very unattractive to 5 being very attractive (for the question on attractiveness of the interface (see Appendix G). The second task was similar to first task. However, participants were required to find and purchase a book by Paulo Coelho, *The Alchimist*, using the LAI. Participants received the same instructions with regards to the text fields that were pre-populated, and, at the end of the second task, they were asked to fill out a short post-task questionnaire (see Appendix H).

After experiencing both interfaces, participants performed the third task, which asked them to choose the interface they would prefer for a future search of a product. They viewed screenshots of both interfaces on the same screen (see Appendix I), and they were prompted to express their preference for either one of the interfaces. Following this task, participants completed a brief survey assessing various aspects of their experience with both interfaces (see Appendix J). Once they completed the survey, they were thanked and informed that they could leave the testing room. At the end of their participation, participants were told the basic purpose of the study.

Response Measures and Data Analysis. Accuracy (number of clicks) and speed of task completion (in seconds) data were measured from the participants' interaction with the two interfaces. A goal number of clicks was set as a measure of the accuracy with which each task on each interface was carried out. The ideal number of clicks on HAI was set to 7 clicks and on LAI the ideal number was set to 9 clicks. Additionally, subjective data of their experience with the two interfaces (in regards with the attractiveness, ease of navigation, and future use of the interfaces) were analyzed to assess participants' preference for one of the two interfaces. Participants were asked which one of the interfaces they would prefer and presented with two options to choose from: Interface X and Interface Y.

Accuracy and speed were analyzed using a paired-samples *t* test with Cohen's d as the effect size measure. For this analysis, G*Power (Faul, Erdfelder, Lang, &

Buchner, 2007) suggested that a total sample size of 34 was sufficient for these analyses (power = .80, alpha = .05, and a medium effect size). Next, the percentage of participants who chose each interface after completing the third task was compared using the chi-square goodness-of-fit test. For this analysis, Cohen (1992) suggested that a total sample size of 87 would be sufficient (power = .80, alpha = .05, and a medium effect size). In addition to the response measures described above, subjective data were collected in regards with participants' characteristics, such as experience with online shopping and their experience with the two interfaces and preference. Three chi-square goodness-of-fit tests were conducted to analyze these data with regards to participants' preference in terms of attractiveness, navigation, and preference for future use. For all tests, alpha was set to .05.

Results

All 70 participants (100%) successfully completed the task using the HAI, whereas 62 participants (88.6%) successfully completed the task on LAI and 8 participants (11.4%) abandoning the task using this interface. The speed of task completion (in seconds) was measured from the participant interaction with both interfaces. One of the hypotheses of this study was that the HAI would require less time to complete the task. Table 1 summarizes the mean duration on task for both interfaces for all 70 participants.

Table 1

Descriptive statistics for speed of task completion (all participants)

Interface	*M*	*SD*	*N*
HAI	98.99	58.95	70
LAI	88.19	47.35	70

As seen in Table 1, participants spent more time conducting the task on the HAI than on the LAI. A paired-samples *t* test showed that this difference was not significant, $t(69) = 1.17$, $p = .12$, one-tailed, $d = 0.20$.

Accuracy (number of clicks) data were measured from the participant interaction with the two interfaces. The second hypothesis of the study was that the high-affordance interface (HAI) would require fewer clicks to complete the tasks. Table 2 depicts the descriptive statistics for this hypothesis.

Table 2

Descriptive statistics for number of clicks (all participants)

Interface	*M*	*SD*	*N*
HAI	10.96	3.45	70
LAI	12.29	5.08	70

As hypothesized, participants made fewer clicks when using the HAI than when using the LAI. A paired-samples t test revealed that this difference was statistically significant, $t(69) = -1.92$, $p = .029$, one-tailed, $d = -0.31$.

Preference data for one of the interfaces were also collected. The third hypothesis of the study stated that, after experiencing both interfaces, more participants would choose the HAI over the LAI. A chi-square goodness-of-fit test was used to determine if participants preferred HAI over LAI. The null hypothesis stated that the participants would show no preference between the two interfaces. As seen in Table 3, significantly more participants chose the HAI over the LAI.

Table 3

Chi-square test of goodness-of-fit results for preference task

N	HAI (%)	LAI (%)	χ^2	*Df*	*P*
70	69 (98.6%)	1 (1.4%)	66.06	1	<.001

After interacting with each interface, participants were asked to fill out a short post-task questionnaire assessing the difficulty/easiness, performance and attractiveness of each interface. Values could range from 1 to 5, with higher values indicating higher ratings for the characteristic in question. Table 4 depicts the descriptive statistics for responses to these post-task questions following task 1 and task 2.

Table 4

Descriptive statistics for responses to post-task questions

Question	HAI			LAI		
	M	*SD*	*N*	*M*	*SD*	*N*
Easiness	3.23	0.97	70	2.81	1.13	70
Performance	3.50	0.70	70	3.35	1.25	70
Attractiveness	1.70	1.01	70	2.17	1.14	70

Final questionnaire summary

Self-reported data regarding the participants' experience with the two interfaces were also collected. In the final questionnaire, participants were asked which interface they thought was more attractive, which interface was easier to navigate through, and which interface they were more likely to use in the future. A chi-square goodness-of-fit test was performed to determine whether participants rated the two interfaces differently in terms of overall attractiveness, easiness and future use. Table 5 depicts the descriptive statistics and chi-square results for these questions.

Table 5

Results for preference questions

Question	HAI	LAI	χ^2	*Df*	*P*
Which interface was more attractive?	65 (92.80%)	5 (7.10%)	51.43	1	< .001
Which interface was easier to navigate through?	67 (95.70%)	3 (4.20%)	58.51	1	< .001
Which interface are you more likely to use in the future?	68 (97.10%)	2 (2.80%)	62.23	1	< .001

At the end of each of the three preference questions, participants were asked to describe their choice for either of the two interfaces using a free-response option. Selected responses from participants who chose the HAI are presented in Table 6, organized by themes and categorized by the three levels of the SRK model the responses represent. Appendix J contains a detailed presentation of all free responses in the study.

None of the participants who chose Interface Y provided a description for their choice.

Table 6

Participants' free responses when they chose Interface X in the preference questions

Question	Themes	Sample responses	S-R-K
Which interface was easier to navigate through? Why?	Search box	"Buttons and search box easier to find"	S, R
	Buttons	"The colored buttons helped me find my way"	S, R
	Hyperlinks	"The clear hyperlinks and buttons"	S, R
		"It was clearer where to go and what to click on"	S, R
	Checkout process	"Checkout process is more similar to what I used before".	R
Which interface will you be more likely to use in the future? Why?	Functionality	"I would use the more functional interface that was quicker and easier to navigate"	S, R
		"Easier and faster to use"	S
	Affordances	"It is more affordable than the other"	S
		"X was more intuitive, features were placed consistently"	S

Table 6 (continued)

Question	Themes	Sample responses	S-R-K
	Visual flow	"More physical representations to the interface and better visual flow"	S, R
		"Easier to use - more intuitive"	S, R

Post-hoc Analyses

Two supplemental analyses were conducted on speed of task completion and accuracy data collected from the expert users. Table 7 depicts the descriptive statistics for speed of task completion for the expert users on time on task for both interfaces.

Table 7

Descriptive statistics for speed of task completion (expert users)

Interface	*M*	*SD*	*N*
HAI	99.00	55.40	48
LAI	83.92	37.81	48

Expert users spent more time conducting the task on HAI than LAI. A paired sample t test showed that this difference was not significant $t(47) = 1.53$, $p = .065$, one-tailed, $d = 0.32$.

A separate analysis was also conducted on accuracy data collected from the expert users. Summarized in Table 8 are the descriptive statistics for expert users on number of clicks for both interfaces.

Table 8

Descriptive statistics for number of clicks (expert users)

Interface	*M*	*SD*	*N*
HAI	10.90	3.50	48
LAI	11.77	3.87	48

Expert users made fewer clicks when using the HAI than when using the LAI. A paired-samples *t* test revealed that this difference was not statistically significant, $t(47) = -1.25$, $p = .109$, one-tailed, $d = -0.24$.

Discussion

The purpose of this study was to determine the effects of a webpage interface design based on Rasmussen's SRK model on user performance when applied in a simple consumer situation of conducting an online shopping checkout. The SRK model, previously tested in complex situations, describes an interface that supports the direct perception of affordances while providing different levels of cognitive control. These embedded affordances provide information that helps users perform an action of interest with the least amount of cognitive effort (Rasmussen & Vicente, 1989, p. 527) and the smallest number of errors (Wickens, 2000, p. 338).

The first prediction of the study was that the high-affordance interface (HAI) would significantly *decrease* the time needed to complete the task compared to the low-affordance interface (LAI). However, participants spent more time searching for a product and conducting the checkout with the HAI than with the LAI. Consequently, the results did not support this hypothesis. According to Wickens (2000), time is considered to be a critical measure of performance quality for a person interacting with a system. One of the guidelines provided by Vicente and Rasmussen (1992) was that an interface should be designed in a way that allows users "to effectively rely on lower levels of cognitive control" (p. 598). Even when the task requires lower levels of cognitive control, higher levels might also be triggered because "the level of cognitive control activated is determined not only by how information is presented but also by task demands and the operator's level of skill" (Vicente and Rasmussen, 1992, p. 598). The HAI was designed with information that guided users through the interface (e.g., hyperlinks, clearly labeled buttons, position of elements on the interfaces, features placed consistently across the interface, easy navigation pathway) and extra information that supported user decisions (e.g., clearly marked star reviews of the product, information on the shipping before engaging in the actual checkout). Although it is important to afford specific actions that might support users in the decision-making process, this extraneous information might take longer to process compared to an interface, such as the LAI, that does not have this information. However, although users took longer with the HAI, the difference was relatively small and not statistically significant.

The second hypothesis stated that participants would make fewer clicks when completing the task using the HAI compared to the LAI. This was found to be true, the difference was statistically significant, and this hypothesis was supported. Thus, the HAI outperformed the LAI in terms of the accuracy of performance (number of clicks). Accuracy is a measure of how many mistakes people make when conducting a task. In this study, the accuracy was measured through the number of clicks required for each task on each interface because a smaller number of clicks needed to successfully accomplish a task meant fewer errors.

According to Wickens, “in decision making and diagnosis, accuracy is the most important measure of performance” (Wickens, 2000, p. 338). By promoting more accurate performance, the HAI appeared to support lower levels of cognitive control while requiring mostly Skill-based and Rule-based behavior compared to the LAI which required more problem-solving skills to complete the task. Knowledge-based behavior was not necessary during the task. Furthermore, all 70 participants successfully completed the task on HAI (100%), whereas only 62 participants (88.6%) were able to complete the task on LAI. Therefore, when creating a consumer interface, a designer should consider embedding the type of affordances that support Skill- and Rule-based behavior in order to help user perform a task with the least amount of cognitive effort.

The third hypothesis stated that participants would prefer the HAI compared to the LAI after using each interface. Support was found for this hypothesis. User preference is important when evaluating interfaces, and strong empirical evidence suggests that people have a definite preference for interfaces that require lower levels of cognitive control (Vicente & Rasmussen, 1992, p. 597). Participants' preference was overwhelmingly in favor of the HAI. Participants reported that the HAI was superior to the LAI in terms of ease of navigation and attractiveness. Furthermore, significantly more participants reported that they would likely use the HAI over the LAI in the future.

The 48 participants who provided the self-report data were all students enrolled in a graduate-level human factors class. Many of these students have academic and/or professional experience in evaluating interface designs. Therefore, they can be considered "expert" users, and their positive evaluation of the HAI confirms its superiority over the LAI. These participants frequently mentioned that the HAI was better because it had a more effective and efficient design that guided them through the task. In addition, their preference for the HAI was partly due to the fact that it better simulated the e-commerce experience than did the LAI. One important factor that made the HAI superior to the LAI was that it provided users with interface elements that helped them complete the tasks at the Skill-level of behavior. For example, the HAI had visible buttons and clickable fields. It also used colors to add salience effects (e.g., bright blue, underline for hyperlinks and grey buttons for proceeding to checkout) and provided a clearly marked search bar above the fold. These kinds of affordances promoted more effective shopping behavior that resulted in a better user experience than that provided by the LAI.

The self-reported data were overwhelmingly in favor of HAI. The HAI was considered more attractive by the expert users because of the distinctiveness of the search box, which is considered first choice when searching. According to the self-reported data on HAI, the search box is positioned at an optimal level which makes it easier to find relevant information on the interface. Furthermore, naming conventions did not change throughout the interface, which provided users with Rule-based behavior elements.

Previous research has been conducted on the SRK model in complex situations to help user to cope with “unanticipated events” (Vicente & Rasmussen, 1992, p. 592) and error (Rasmussen & Vicente, 1989, p. 517). Various studies have attributed the benefit of providing the user with affordances that support problem solving (Pawlak & Vicente, 1996; Sharp & Helmicki, 1998; Xu et al., 1999), and showed that the interfaces built on the SRK model supported better performance in terms of faster detection and more accurate diagnosis. The design of the present study reflected the reproduction of real-world tasks in a more controlled environment. The flow of interaction in the study, which was realistic, focused on how affordances provide guidance to users when conducting a task, but not how users would cope with unanticipated events when conducting those tasks. Future research is recommended to study this component of the SRK model in HCI, specifically in website design.

One limitation of this study is that the testing system had problems loading pages quickly, and the time lag might have led to some confusion and frustration for participants. The issue was caused by both the testing system and the Internet connectivity in the computer lab in which testing occurred. Although these technical issues might have affected the overall results, they occurred in both experimental conditions, so neither interface was differentially affected. A second limitation resulting from the testing situation was that the participants were talking with each other in the waiting area outside of the lab. This may have caused some distraction to those participants who were being tested at the time. In addition, the waiting time might have caused the participants to become frustrated, and this could have influenced their performance and free responses.

Another limitation concerns the sample of participants. As mentioned earlier, qualitative data from human factors graduate students were recorded and many of these students have extensive experience evaluating website interfaces. These students are trained in examining good practices on designing interfaces, and they brought a relatively high level of expertise about system visibility and website usage. This may have brought more criticism when evaluating the interfaces in terms of standards of designing interfaces and less a valid experience of a normal user interacting with the interfaces. Furthermore, as user experience professionals, human factors graduate students are familiar with the prototyping tools used to create the interfaces. This likely affected these participants' experiences with the interfaces because they were aware that not all buttons were clickable, and they tended to search the screen for clickable buttons rather than searching and understanding the meaning of the buttons. Due to a technical difficulty, 22 participants in the study, who were undergraduate psychology students, were not able to provide their responses. Their data likely would have been more impartial due to their lack of experience with designing and evaluating interfaces. In order to understand different perceptions of user interfaces, future research should include and analyze qualitative data from different categories of users. It would be interesting to see if a novice group and an expert group differ significantly in the way they perceive a high-affordance interface.

The study was conducted using two different interfaces, which participants used to perform simulated online shopping tasks. The scenarios were detailed and the tasks were realistic, but future studies on this topic could benefit by assessing more realistic tasks. In real-life situations, users may not focus exclusively on the task of buying a single product, so they might become distracted with browsing other items or conducting different activities (e.g., checking their e-mail). The use of these prototypes imposed limitations with regards to participants' experience because prototypes do not have the complete functions of an actual website. Thus, they did not perfectly emulate a natural web-browsing experience. Nevertheless, this study assessed realistic tasks in a controlled environment, which reflected a concern for internal validity over external validity. In the future, a more natural environment with real websites may be important to consider. Some of the fields that would have required entering data were pre-populated because entering data was not the scope of the study. Although this was done for convenience and made the task easy to perform, using pre-populated data fields reduces the ecological validity of the study. When proceeding to an online checkout, entering data during online shopping is a key part of the process. This experience can be cumbersome in some instances, and users expect “data entry of an appropriate length, without format restrictions” (Schade & Nielsen, 2013, p. 8). Having participants enter data themselves would have led them to a more realistic feel to the task. Finally, because they were conducting a simulated task using products they did not intend to purchase, the motivation of participants was different than would be the case in a naturalistic situation. Although the aforementioned reasons imposed some limitations on the study, they may also be considered promising areas for future research. It would be interesting to study how users search for a product in a more naturalistic situation and how variables such as how much time it takes to enter real data (e.g., shipping address, billing address, credit card information) influences users’ experiences.

Other limitations involve the software used to build and deliver the experiment. The software had elements that were perceived as distracting by most of the participants (based on their self-report data). In addition, the layout design of the study’s interfaces was somewhat ambiguous. While conducting the task on an interface, at the bottom of the screen there was a minimized window that asked participants to rate their performance on the task, by clicking a “success” or an “abandon” button. This window with two color-coded Success/Abandon buttons was present throughout the whole task to give participants the freedom to rate the task at any time during their performance.

Therefore, the Success/Abandon buttons could have been used at any time during the task even if the participants had not completed the task. In addition to the vagueness of the buttons, after successfully completing the checkout process, there was no on-screen indication informing user what to click next to continue to the survey. Also, the keys for completing the survey at the end of the study were not always responsive. For a future study, it is recommended that the experiment should be streamlined so that participants would not notice the difference between the experiment state and a normal web experience. Furthermore, the recommendation is that the task completion ratings (success/abandon) should appear exclusively at the end of the task to minimize the intrusiveness in participants' activity. Finally, it would be more intuitive to remove the buttons from the bottom window and include them into the webpage itself in a floating frame.

This study also could have been improved by modifying the training protocol for participants. Participants were briefly introduced to the instructions about using the bottom buttons, and the task instructions were presented to participants in digital format throughout the study and before each task. A shorter version of the task instruction was available to participants at the bottom of the screen all the time, but not in a salient manner. Furthermore, there was no feedback from the interface as to the next steps participants should take, and participants had to find the instructions at the bottom of the page on their own. This fact not only created confusion, but it also increased the time on the task. Users rarely look below the fold on a website and tend to scan the information presented on the top of the page (Nielsen, 2010). A more precise training session given by the researcher at the beginning of the sessions in either paper or digital format, would have allowed participants to concentrate on the task, giving them a chance to be more effective.

Conclusion

As anticipated, accuracy data showed that the HAI based on the SRK model supported lower levels of cognitive control and involved mostly Skill-based behavior and Rule-based behavior. Furthermore, participants overwhelmingly preferred the HAI, mostly because it simulated the e-commerce experience better than did the LAI. The results failed to support the hypothesis that the SRK model interface would require less time to conduct a task comparing to a low-affordance interface. In the current study, participants spent more time searching for a product and conducting the checkout when interacting with the HAI than with the LAI. Based on these results, the SRK model may be considered another conceptual tool to make interfaces easier to use and consumer experience more satisfying and enjoyable.

The present study provides support to Rasmussen’s SRK model, which was initiated to understand how performers actually explore interfaces. The performer can reach the goal of the action (acquiring a book on a website) through a better performance (less number of clicks) and enjoyable experience, when provided with the right affordances (HAI’s elements mentioned by self-reported data). The Rasmussen’s model was applied to HAI encourage the performer to make use of the Skill- and Rule-based behavior to ensure the conservation of the limited cognitive resources. The lack of affordances on LAI determined performers to make use of the Knowledge-level behavior, making their experience more troublesome and less enjoyable.

Despite its limitations, this study is one of the first to investigate the extent to which Rasmussen's SRK model can be applied to the design of interfaces for everyday computer-based activities. There is a lack of empirical studies in the HCI field that have applied the SRK framework to the design of embedded interfaces that are meant to be manipulated in less cognitively demanding situations. Most of the previous research on the SRK model has focused on complex situations that require high cognitive demand (e.g., nuclear power plant operation). No previous studies examined the applicability of the SRK model to simpler, everyday situations. Although there was no strong empirical support for the design of this study, the theoretical background provided support for the study's design and predictions.

Therefore, it may be worthwhile to replicate the study, while addressing the limitations mentioned above. Indeed, many questions remain unanswered and further research is needed to investigate the application of the SRK model to interface design in everyday environments.

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Appendix A

Human Subjects Institutional Review Board Approval

SAN JOSÉ STATE
UNIVERSITY

Division of Academic Affairs

Associate Vice President
Graduate Studies & Research

www.sjsu.edu/gradstudies

One Washington Square
San José, California 95192-0025
Voice: 408-924-2427
Fax: 408-924-2612

www.sjsu.edu

To: Dr. Sean Laraway
Department of Psychology
San Jose State University
One Washington Square
San Jose, CA 95192-0120

Gabriela Istan

From: Pamela Stacks, Ph.D.
Associate Vice President
Graduate Studies and Research

Date: April 30, 2013

The Human Subjects-Institutional Review Board has registered your study entitled:

"Designing affordances on embedded interfaces"

This registration, which provides exempt status under Exemption Category 2, of SJSU Policy S08-7, is contingent upon the subjects participating in your research project being appropriately protected from risk. This includes the protection of the confidentiality of the subjects' identity when they participate in your research project, and with regard to all data that may be collected from the subjects. The approval includes continued monitoring of your research by the Board to assure that the subjects are being adequately and properly protected from such risks. If at any time a subject becomes injured or complains of injury, you must notify Dr. Pamela Stacks, Ph.D. immediately. Injury includes but is not limited to bodily harm, psychological trauma, and release of potentially damaging personal information. This approval for the human subject's portion of your project is in effect for one year, and data collection beyond April 30, 2014 requires an extension request.

Please also be advised that all subjects need to be fully informed and aware that their participation in your research project is voluntary, and that he or she may withdraw from the project at any time. Further, a subject's participation, refusal to participate, or withdrawal will not affect any services that the subject is receiving or will receive at the institution in which the research is being conducted.

If you have any questions, please contact me at (408) 924-2427.

Protocol #: F1302083

The California State University
Chancellor's Office
Bakersfield, Channel Islands, Chico, Dominguez Hills, East Bay, Fresno, Fullerton, Humboldt, Long Beach, Los Angeles, Maritime Academy, Monterey Bay, Northridge, Pomona, Sacramento, San Bernardino, San Diego, San Francisco, San José, San Luis Obispo, San Marcos, Sonoma, Stanislaus

Appendix B

Demographic questionnaire

Please answer the following questions about you and your background. Choose the answer that is applicable and fill out the requested information.

1. What is your age? (in years)___________________

2. What is your sex? (choose one)
   - o Male
   - o Female

3. What is your college grade level? (choose one)
   - o Freshman
   - o Sophomore
   - o Junior
   - o Senior
   - o Post-baccalaureate
   - o Graduate student
   - o Other (please name):________________________

4. What is your race/ethnicity? (choose one)
   - o Hispanic, Latino, or Spanish
   - o White
   - o Asian (e.g., Asian Indian, Chinese, Filipino, Japanese, Korean, Vietnamese)
   - o Black/African American
   - o American Indian (North, Central, or South American) or Alaskan Native
   - o Native Hawaiian
   - o Other Pacific Islander
   - o Other (please name):____

5. On average, how many hours per week do you spend using the Internet?
____

6. How often do you shop online (choose the option that best describes the frequency of your online shopping)?
   - o Almost never (about once every six months)
   - o Rarely (about once every two months)
   - o Sometimes (about once a month)
   - o Often (about once a week)
   - o Very often (about once a day)

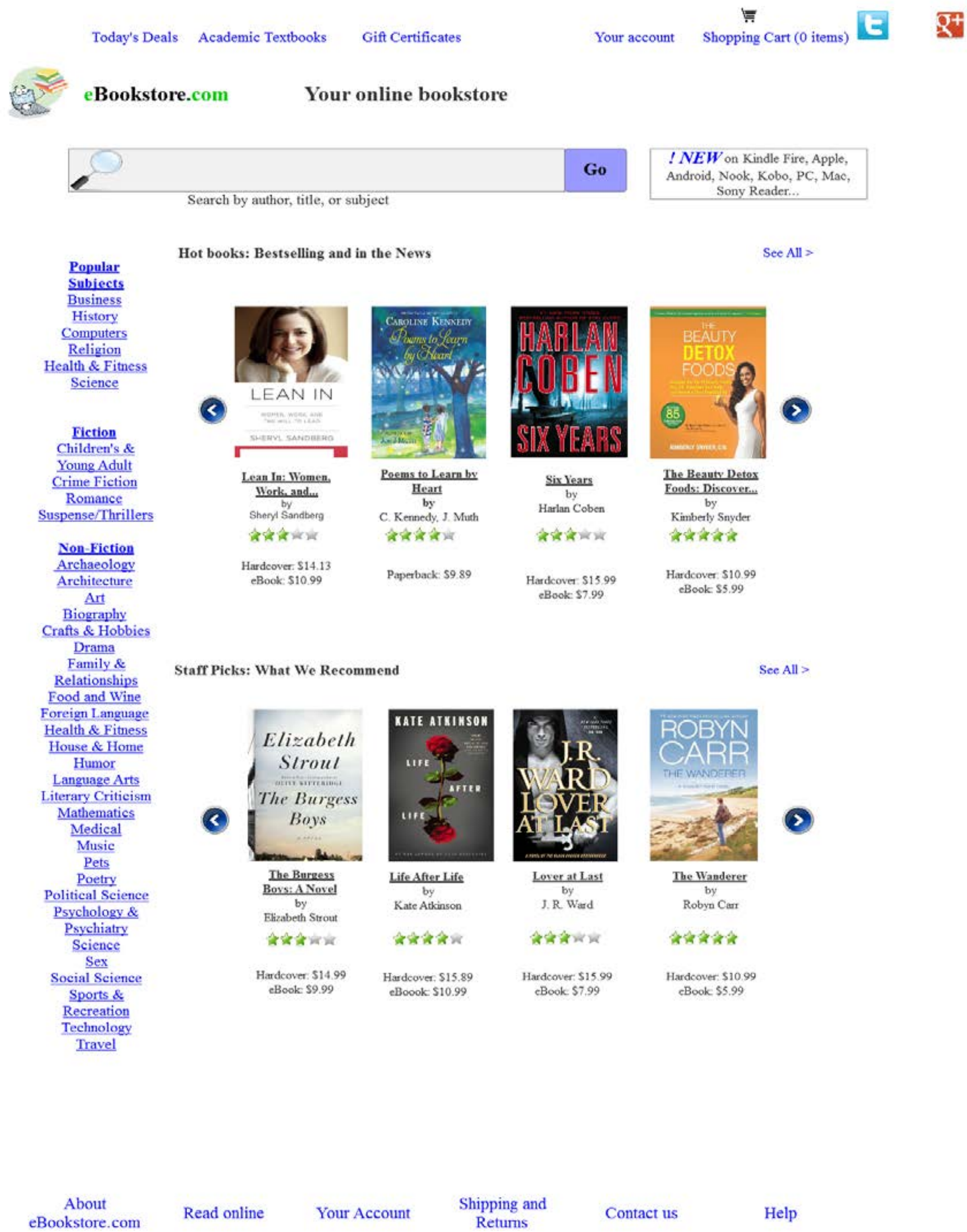
Appendix C

High-affordance interface (HAI) or Interface X

First page of the website

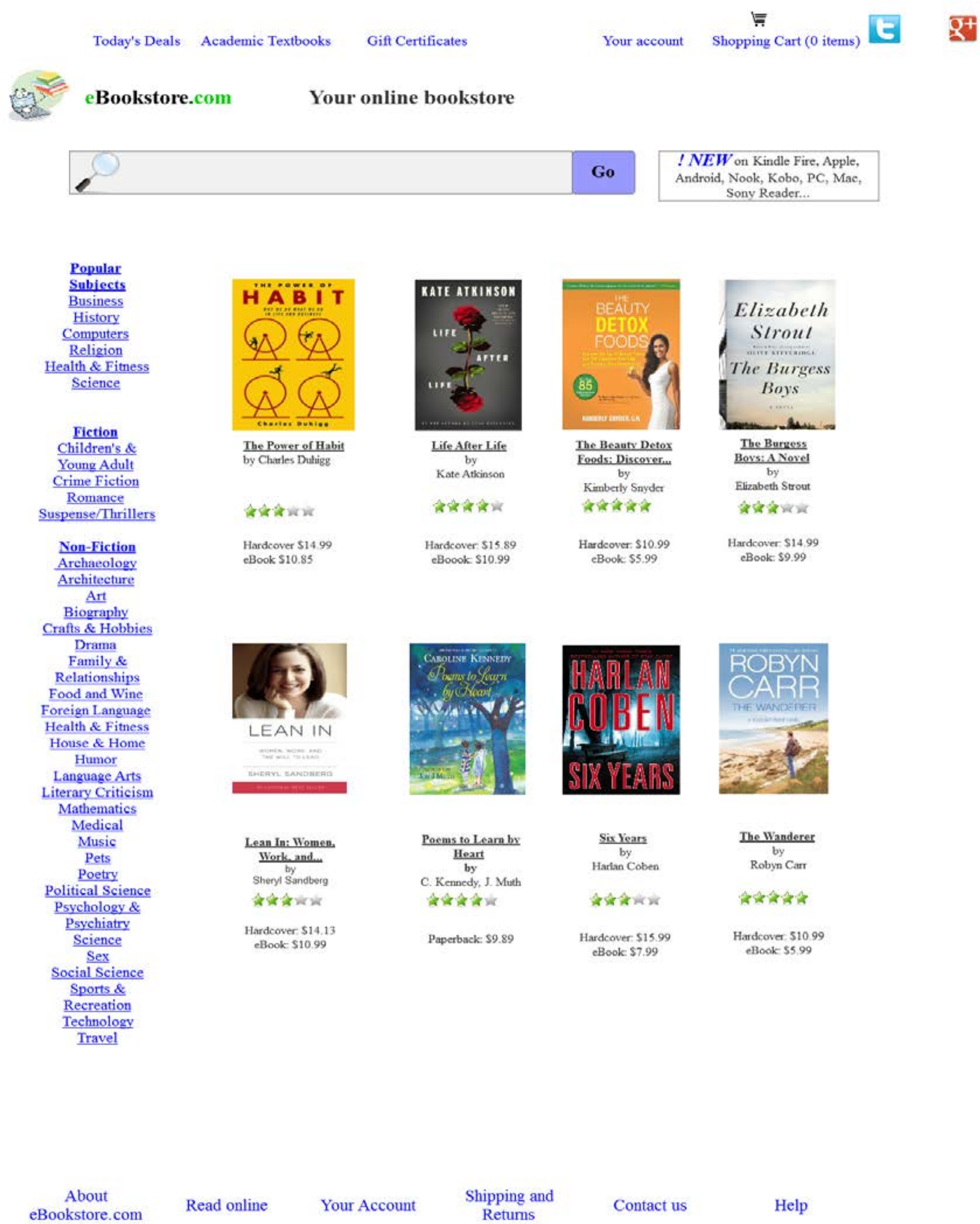
High-affordance interface (HAI) or Interface X

Second page - Home Page



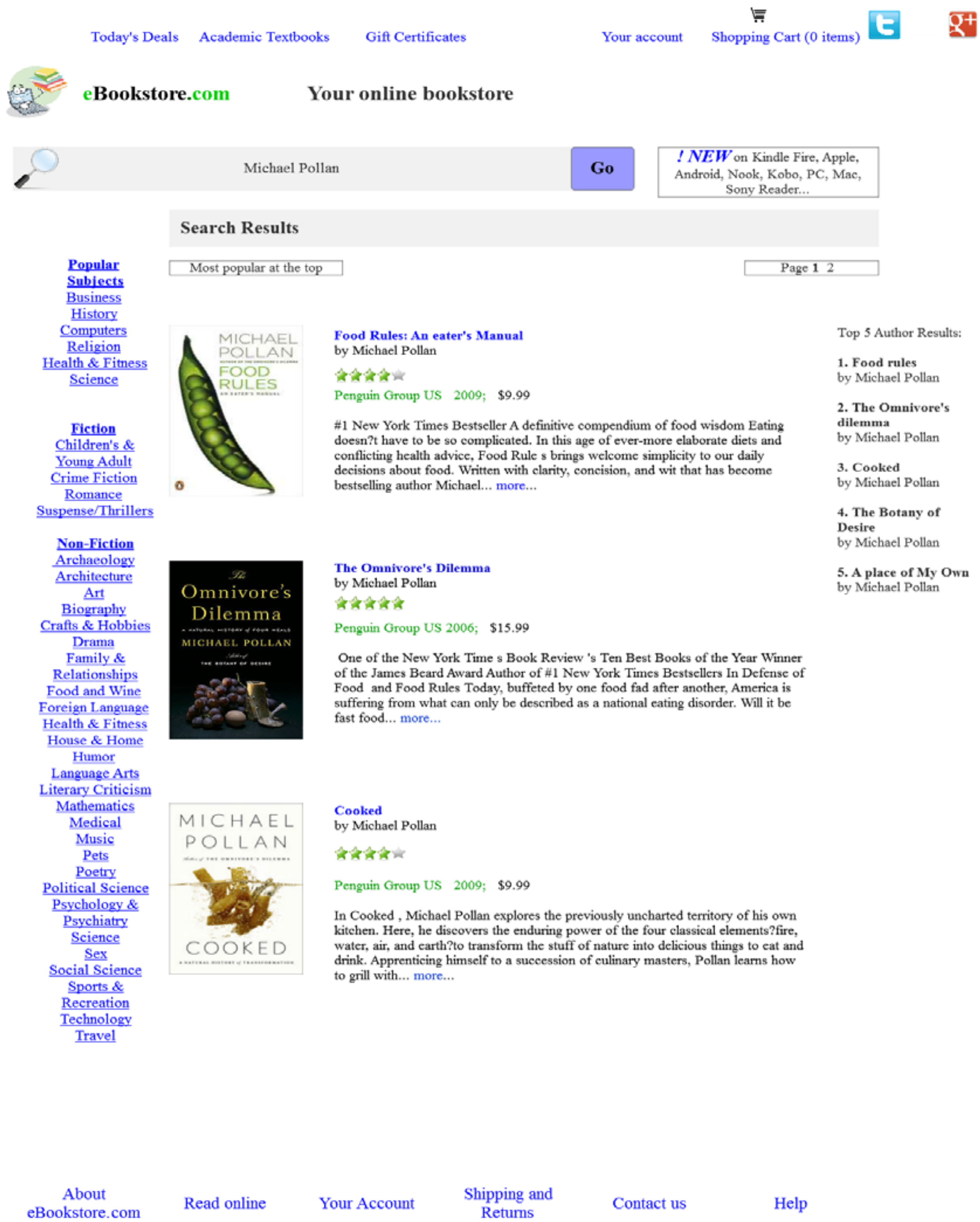
High-affordance interface (HAI) or Interface X

Third page – See All Books



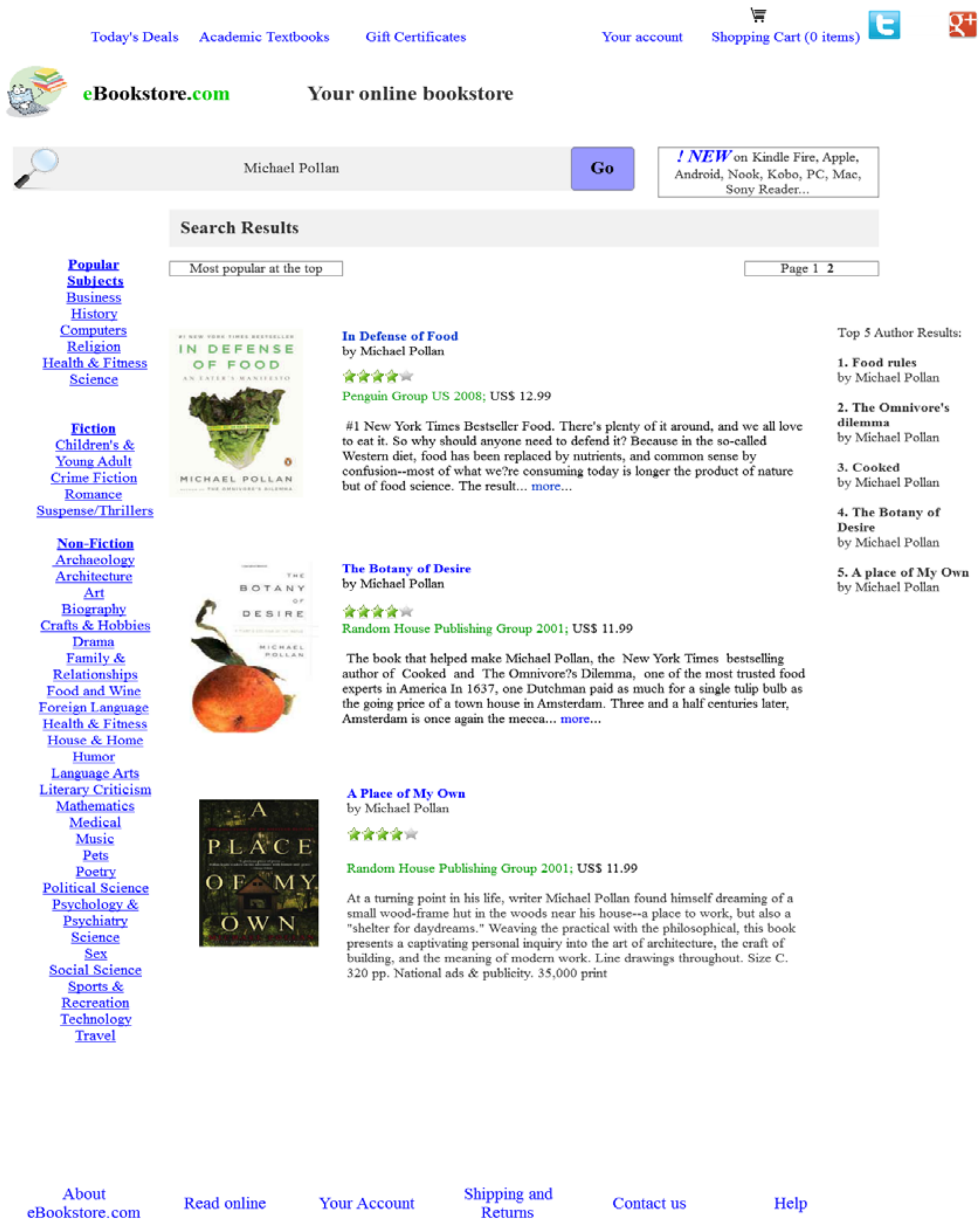
High-affordance interface (HAI) or Interface X

Fourth page – Search Results Michael Pollan (Page 1)



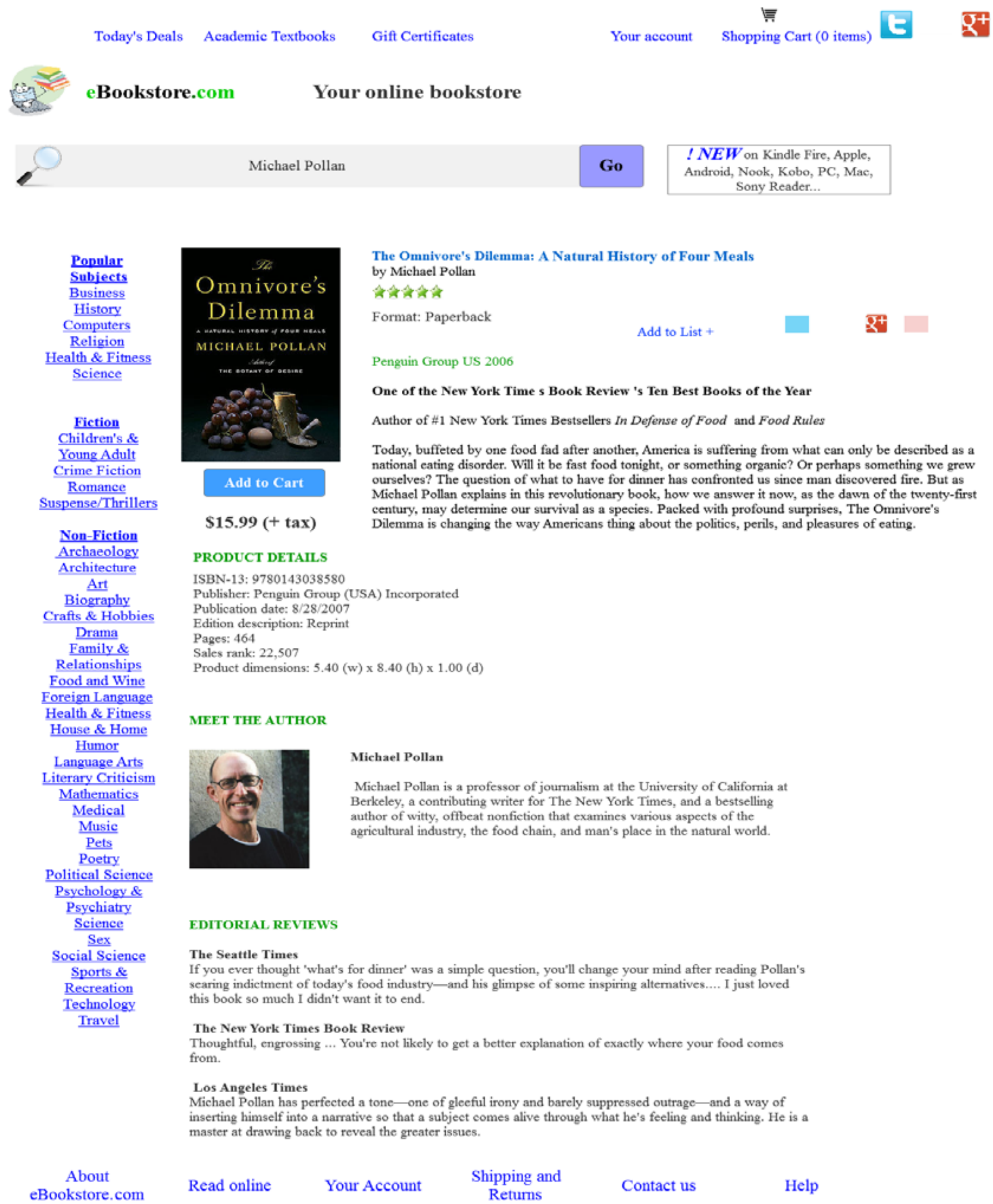
High-affordance interface (HAI) or Interface X

Fifth page – Search Results Michael Pollan (Page 2)



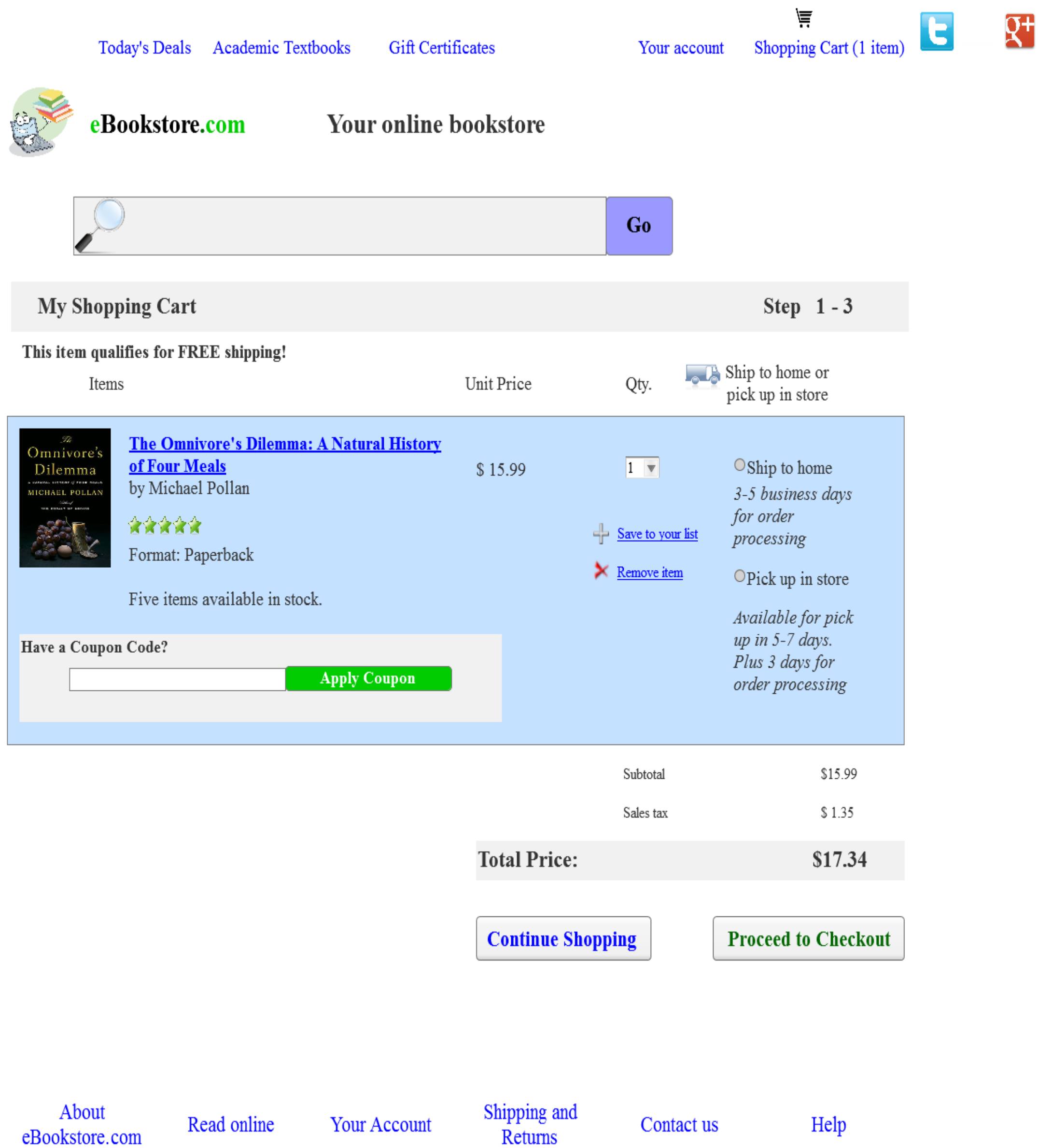
High-affordance interface (HAI) or Interface X

Sixth page –Michael Pollan's book "Omnivore Dilemma"



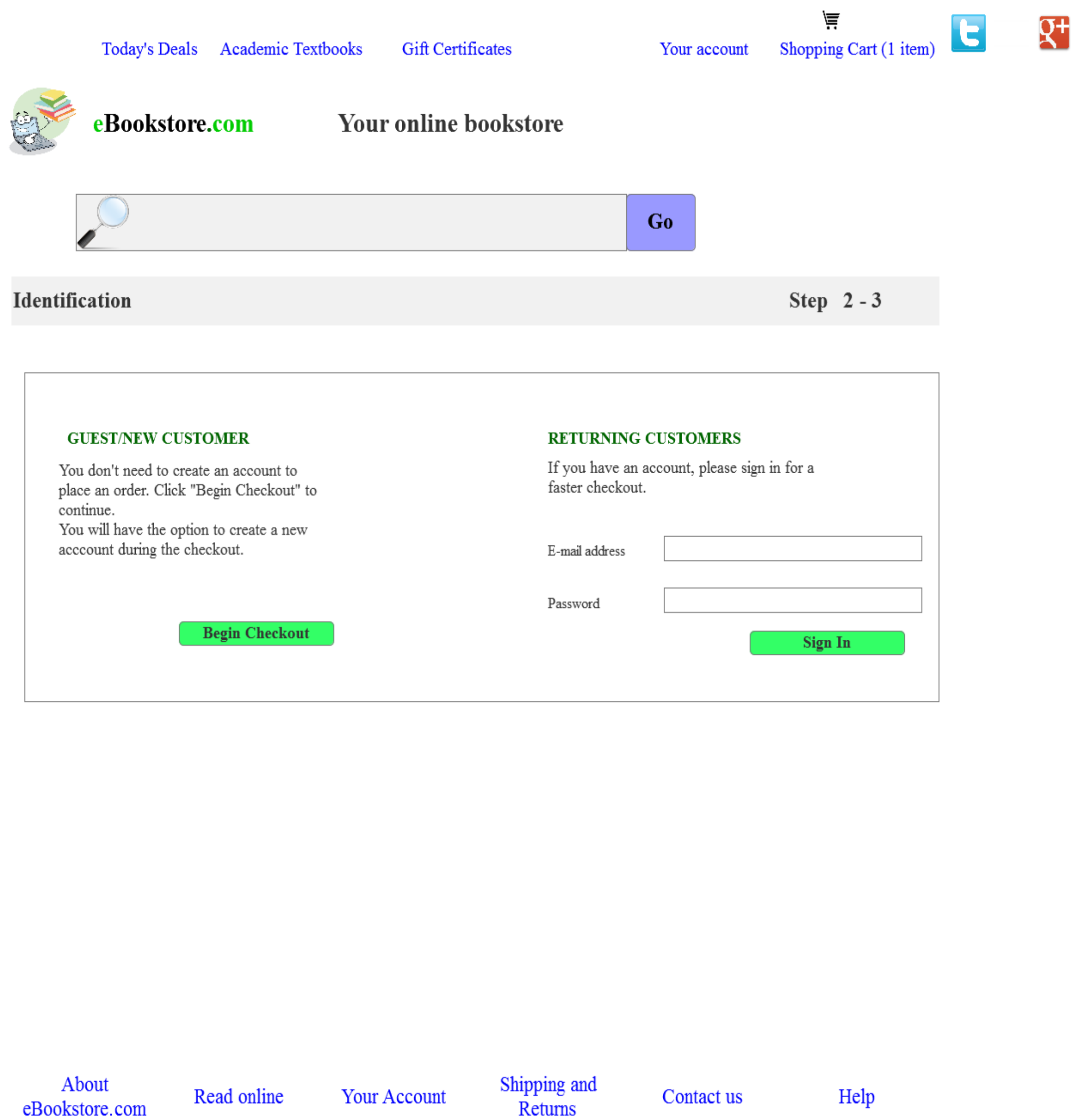
High-affordance interface (HAI) or Interface X

Seventh page – Shopping Cart



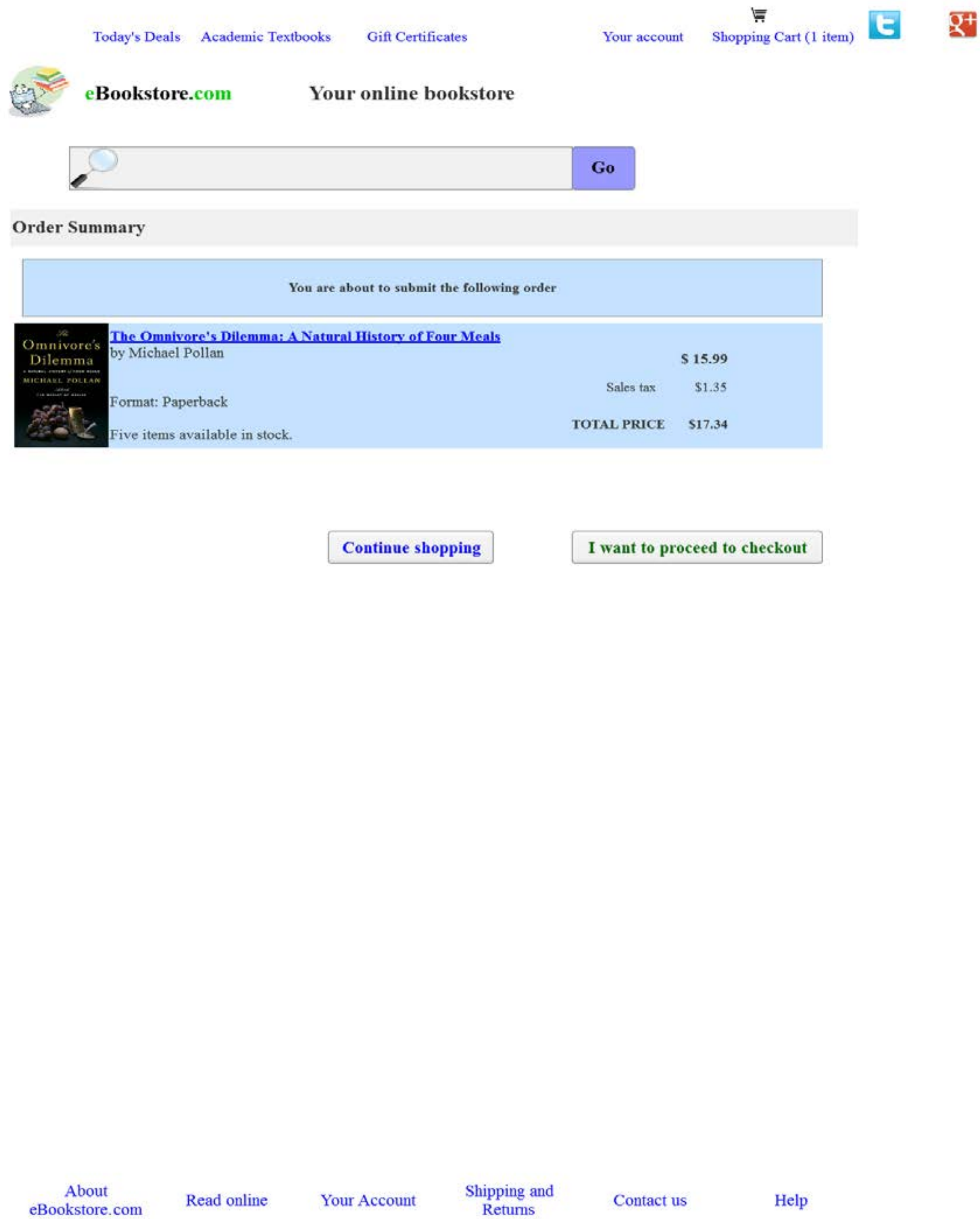
High-affordance interface (HAI) or Interface X

Eighth page – Identification



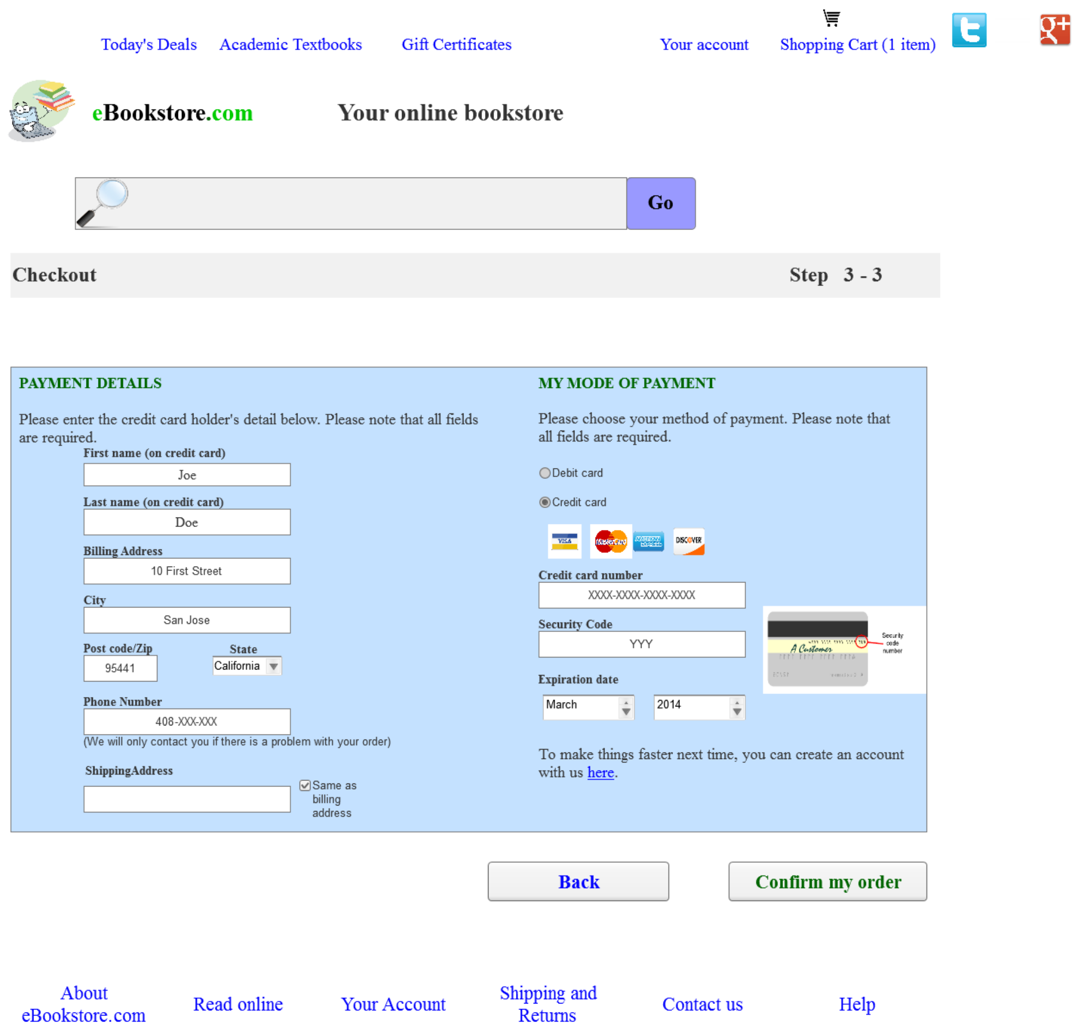
High-affordance interface (HAI) or Interface X

Ninth page – Order Summary



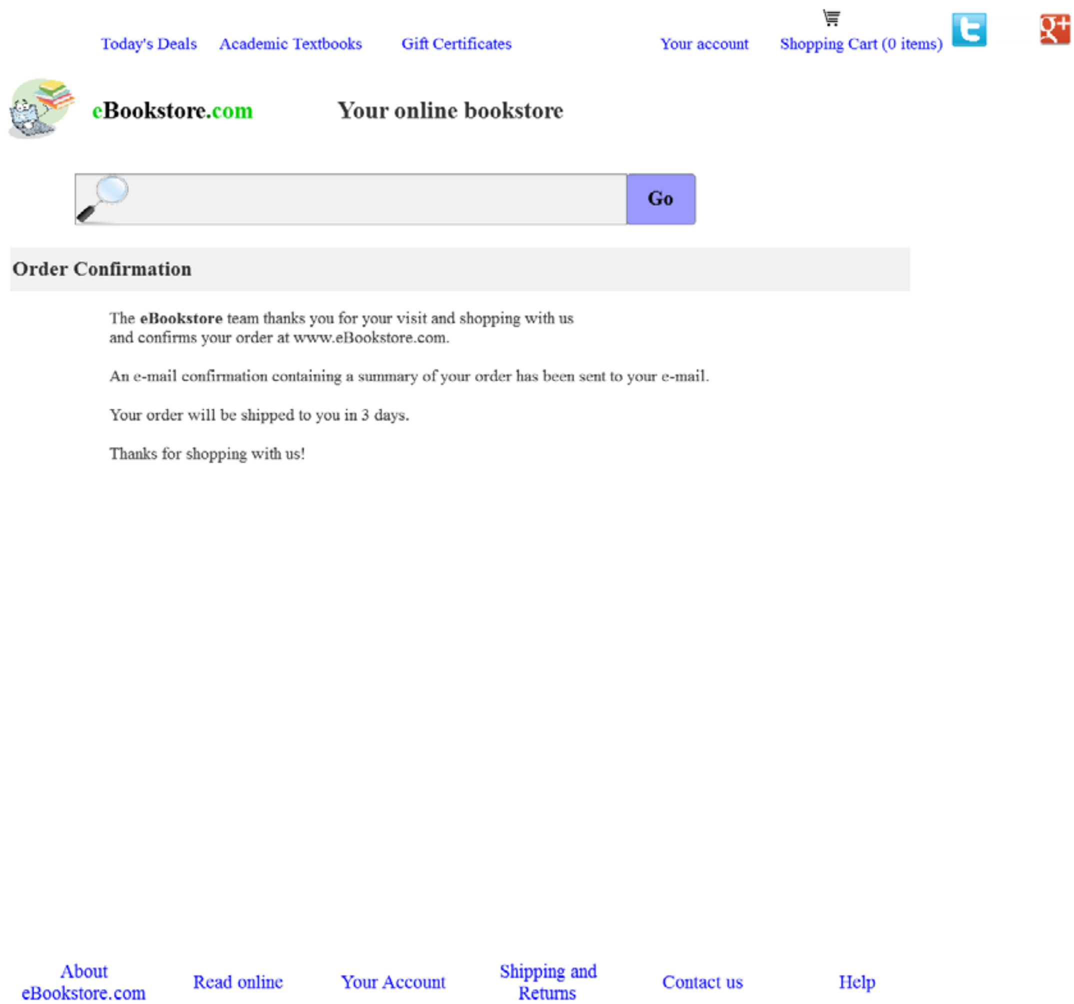
High-affordance interface (HAI) or Interface X

Tenth page – Checkout page



High-affordance interface (HAI) or Interface X

Eleventh page – Confirmation page



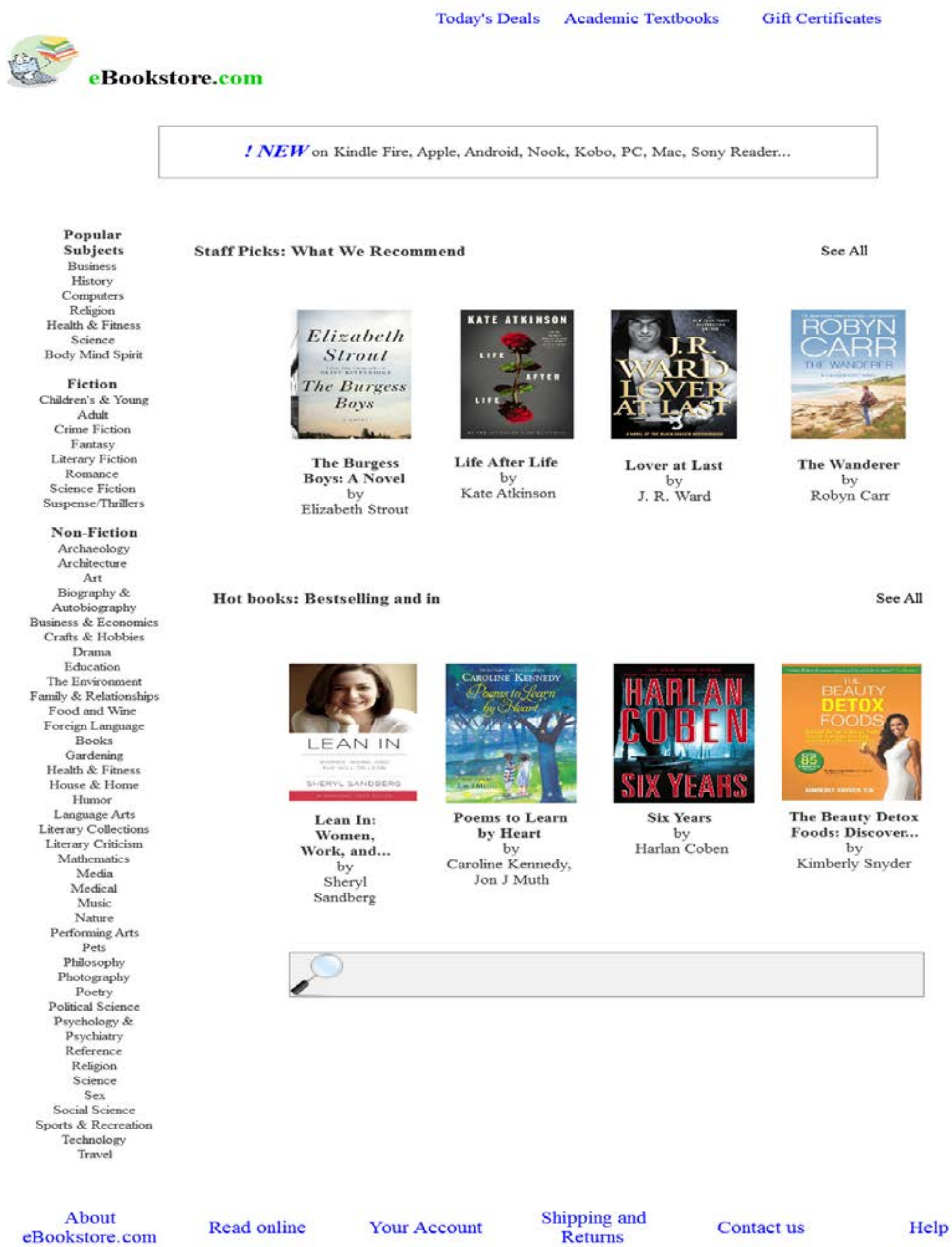
Appendix D

Low-affordance interface (LAI) or Interface Y

First page of the website

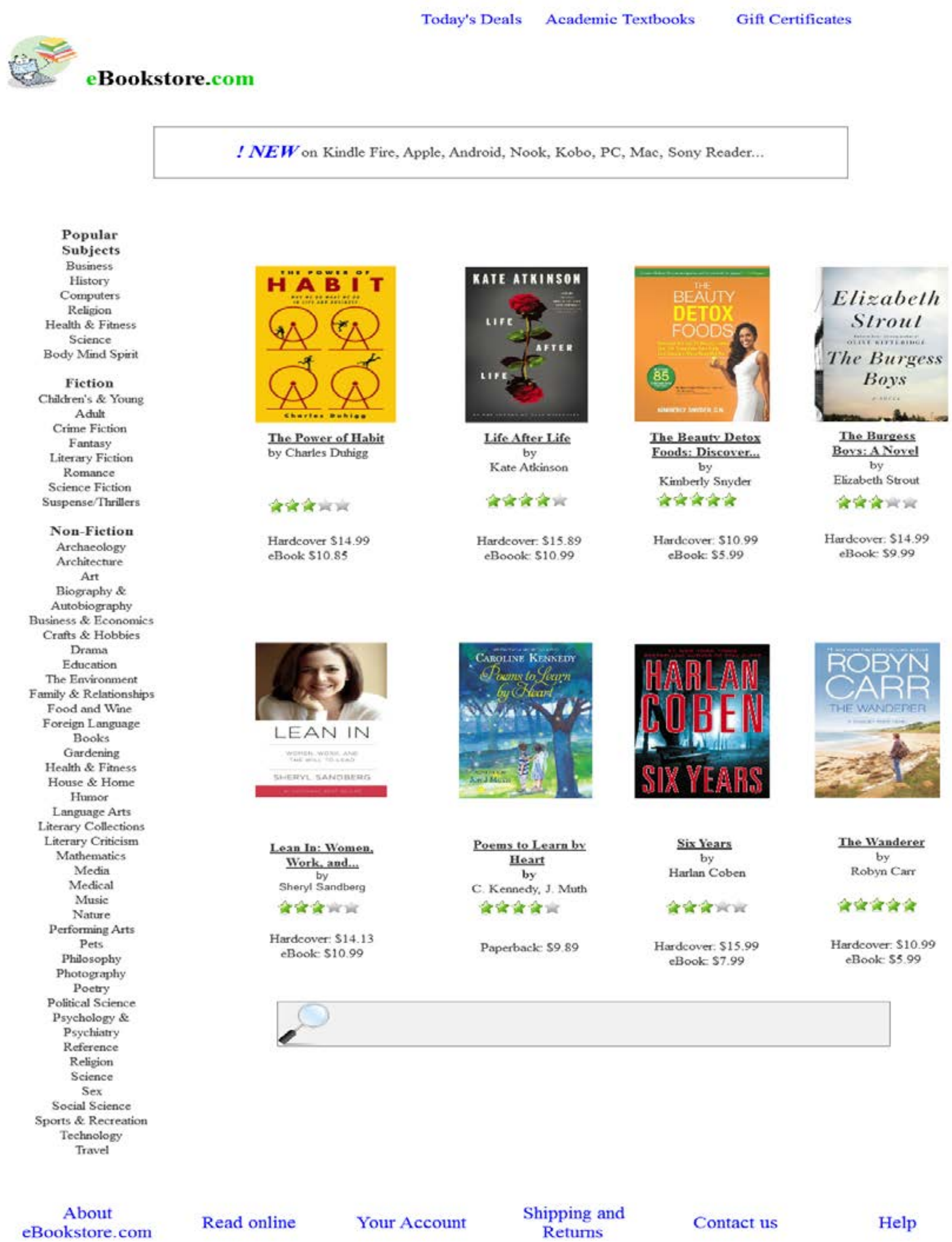
Low-affordance interface or Interface Y

Second page – Home Page



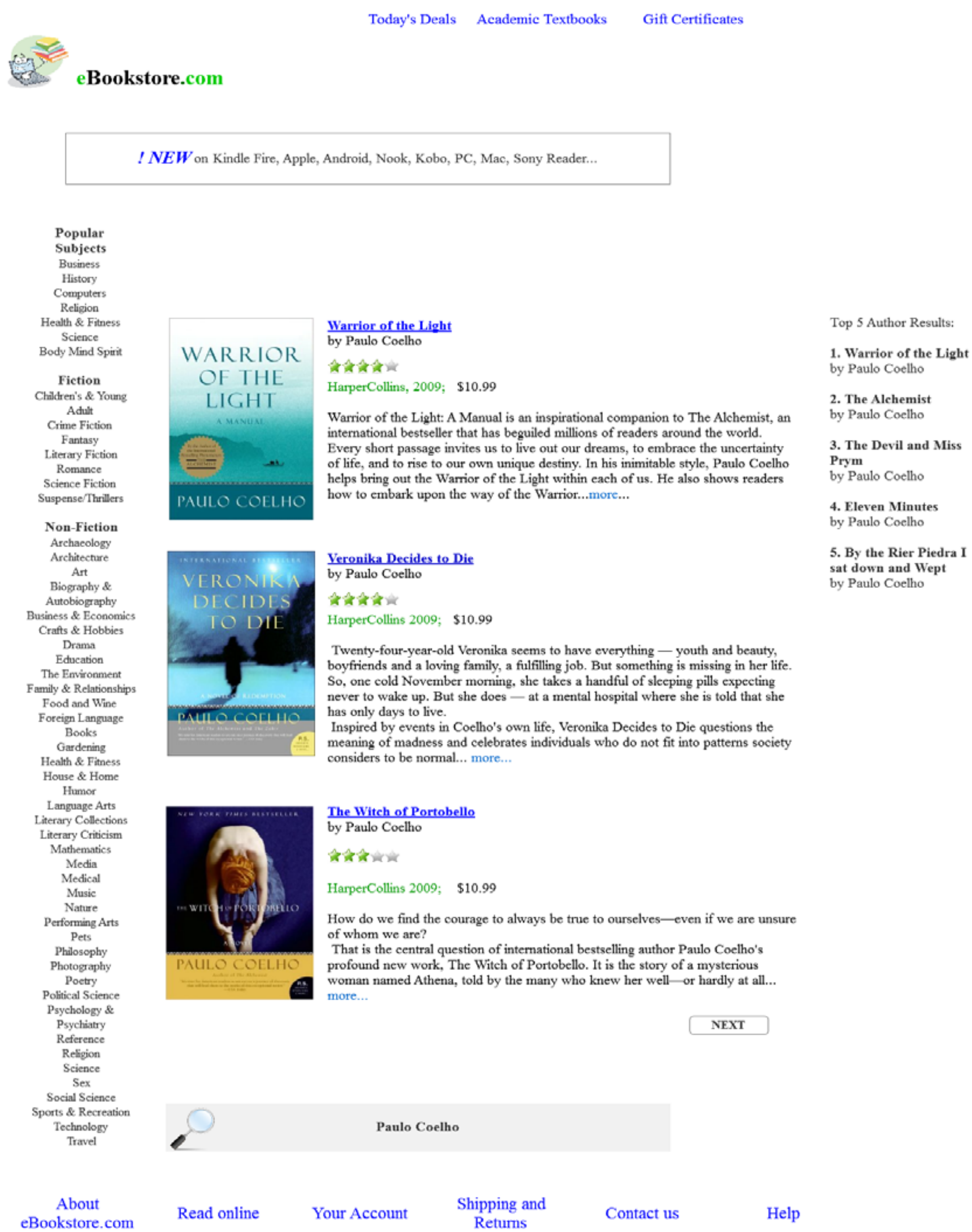
Low-affordance interface or Interface Y

Third page – See All Books



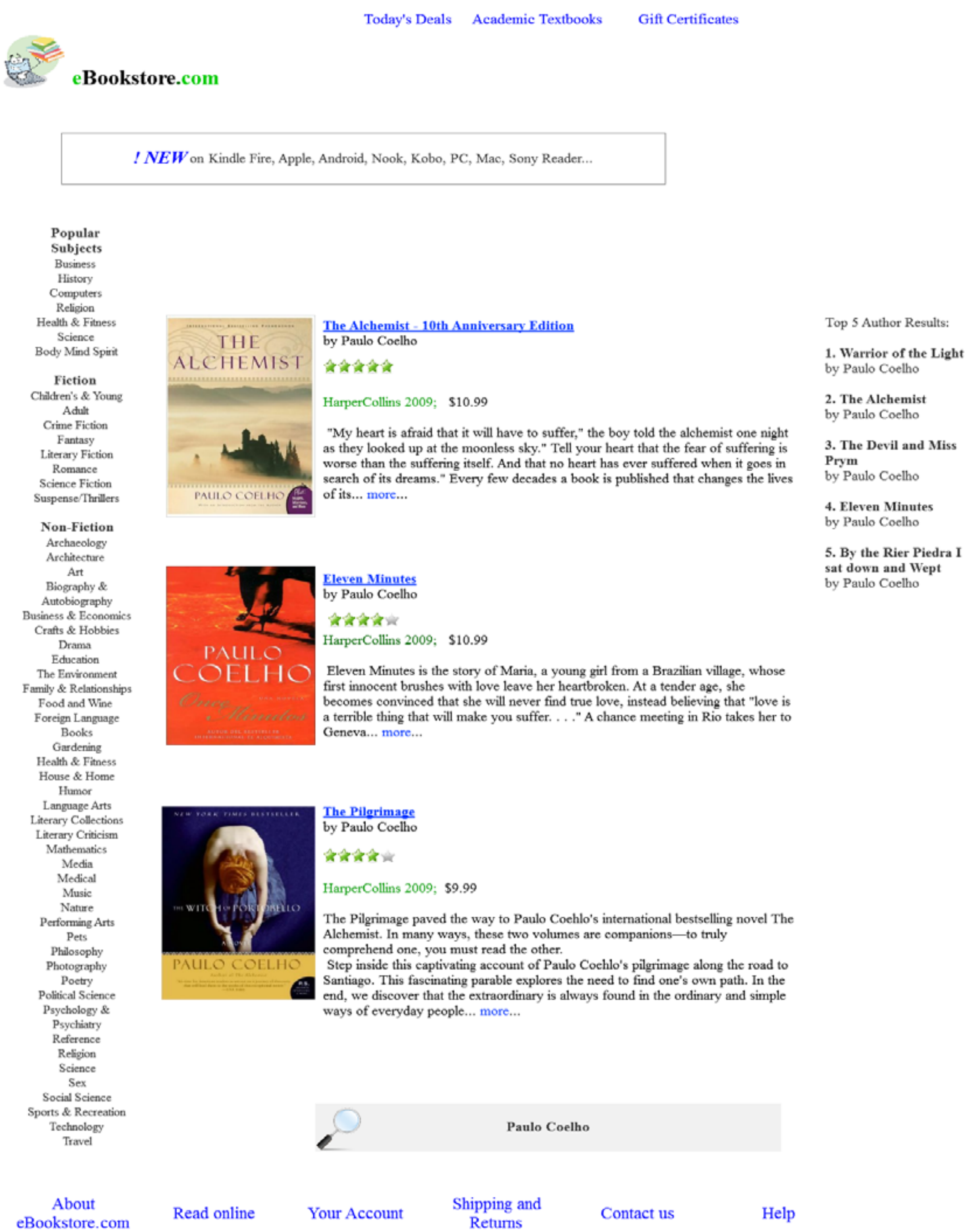
Low-affordance interface or Interface Y

Fourth page – Search Results Paulo Coelho (Page 1)



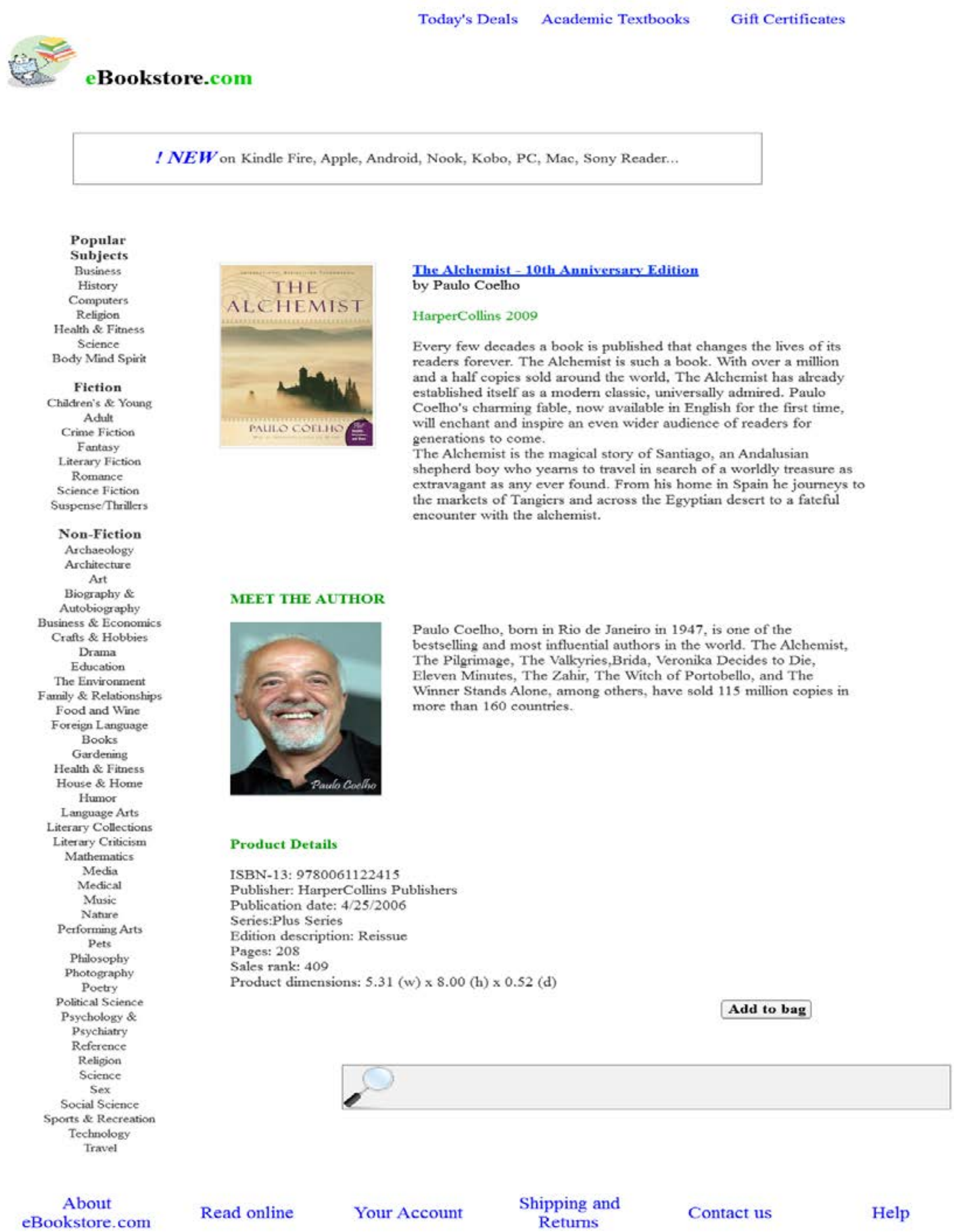
Low-affordance interface or Interface Y

Fifth page – Search Results Paulo Coelho (Page 2)



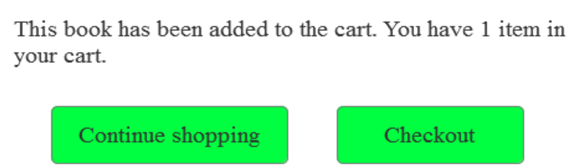
Low-affordance interface or Interface Y

Sixth page –Paulo Coelho's book "The Alchemist"



Low-affordance interface or Interface Y

Seventh page – A pop-up window that requests users to either continue shopping or to start the checkout



Low-affordance interface or Interface Y

Eighth page – Shopping Cart page

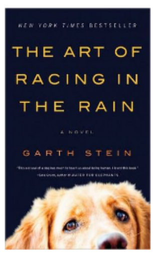
Today's Deals Academic Textbooks Gift Certificates

eBookstore.com

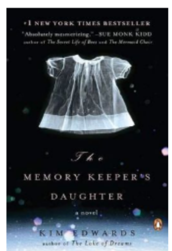
My Shopping Cart

Items	Unit Price	Qty.
The Alchemist - 10th Anniversary Edition	$10.99	1 ▾ Price: $10.99

Customers Who Bought This Also Bought



The Art of Racing in the Rain
by Garth Stein
Paperback $9.15



The Memory Keeper's Daughter
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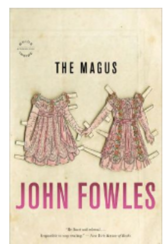

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Low-affordance interface or Interface Y

Ninth page – Identification page

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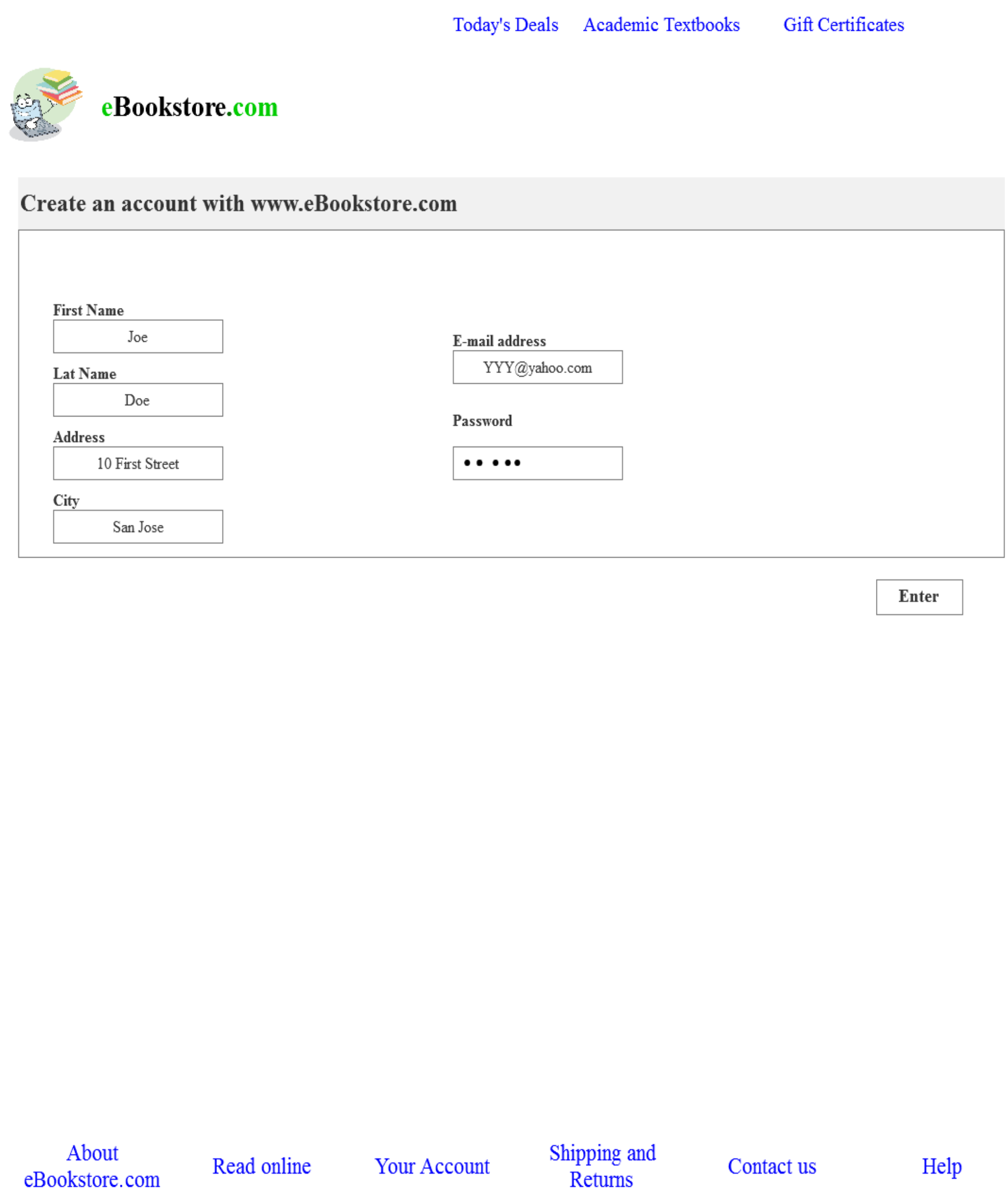
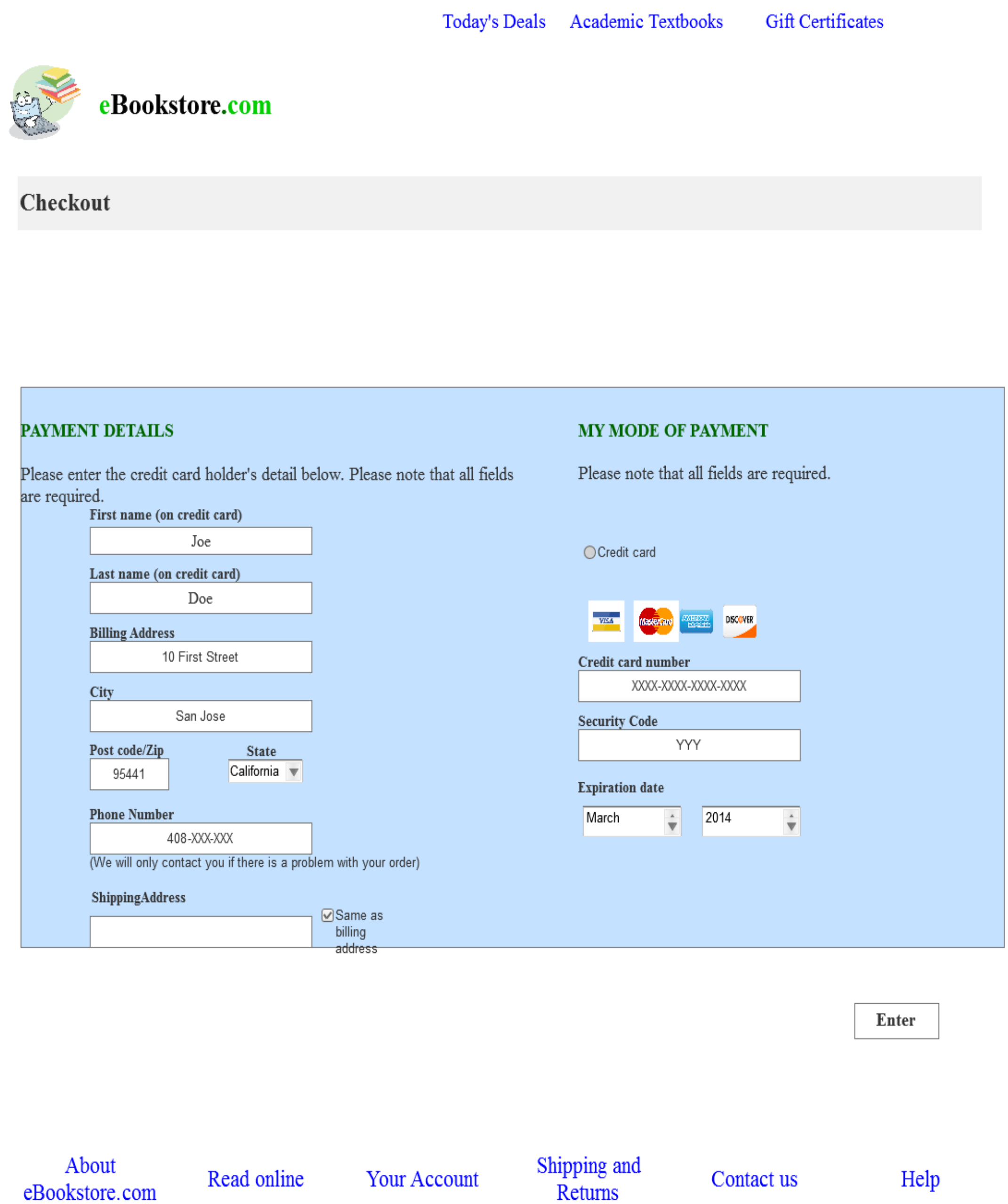
Tenth page – Create an account page



Low-affordance interface or Interface Y

Eleventh page – Checkout page



Low-affordance interface or Interface Y

Twelfth page – Checkout page

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Appendix E

Agreement to Participate in Research

San José State
UNIVERSITY

Department of Psychology
DMH 157
One Washington Square
San Jose. CA
95192-1020
Voice: 408-924-5600
Fax: 408-924-5605
www.psych.sjsu.edu

The California State University:
Chancellor's Office
Bakersfield, Channel Islands, Chico
Dominguez Hills, East Bay, Fresno, Fullerton, Humboldt, Long Beach, Los Angeles, Maritime Academy, Monterey Bay, Northridge, Pomona Sacramento, San Bernardino, San Diego, San Francisco, San Jose, San Luis Obispo, San Marcos, Sonoma, Stanislaus

Consent Form
Agreement to Participate in Research

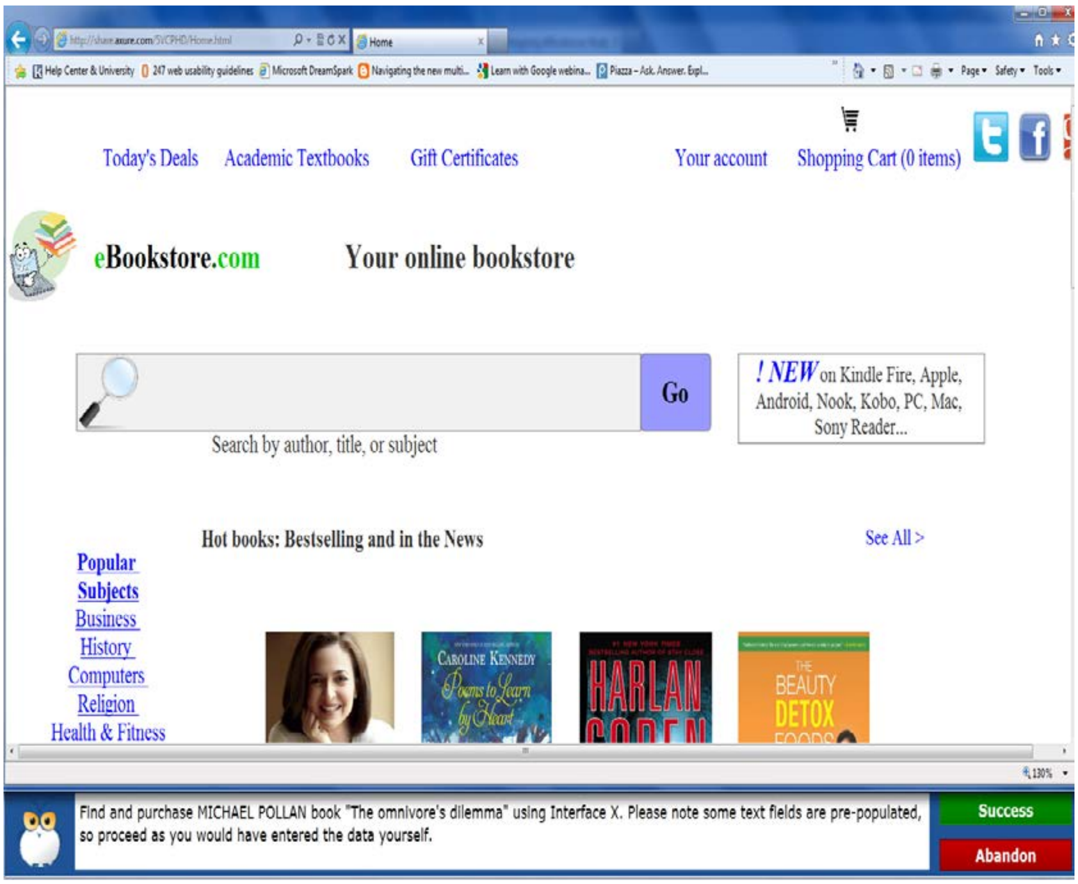
Responsible Investigators: Gabriela Istan & Sean Laraway
Title of Study: Designing affordances on embedded interfaces

1. You have been asked to participate in a study investigating the perception of action cues when shopping on the web.
2. You will be asked to view an e-commerce website selling books. You will be asked to perform simulated online shopping tasks. You will be asked questions about the tasks and basic demographic information.
3. Absolute anonymity of data and records will be maintained. Although the results of this study may be published, no information that could identify specific participants will be collected.
4. Potential risks, discomforts, or adverse effects on your physical, mental, and emotional well-being are no greater than those encountered in daily life.
5. In return for participation in this study, you will earn course credit from your instructor. This study should take about 25 minutes.
6. Questions about this research may be addressed to Gabriela Istan at gabriela.istan@gmail.com. Complaints about the research may be presented to Ronald Rogers, PhD, Chair of the Psychology Department, (408) 924-5652. Questions about a research subjects' rights, or research-related injury may be presented to Pamela Stacks, Ph.D., Associate Vice President of Graduate Studies and Research, at (408) 924-2427.
7. No service of any kind, to which you are otherwise entitled, will be lost or jeopardized if you choose not to participate in this study.
8. Your consent is being given voluntarily. If you do not wish to participate, or feel uncomfortable at any time, you may discontinue participation without consequence. If you decide to participate in the study, you are free to withdraw at any point during the study without any negative effect on your relations with San Jose State University.
9. By clicking the "Next" button, you are providing your informed consent that you agree to participate in this study.

NEXT

Appendix F

The Instructions window was opened all the time at the bottom of the screen, containing a short description of the task and two buttons - Success and Abandon.



Appendix G

Post-task questionnaire (Interface X)

1. How difficult/easy was it for you to perform this task on Interface X?

1	2	3	4	5
Very Difficult		Neutral		Very Easy

2. How do you rate your performance using Interface X?

1	2	3	4	5
Not Successful		Neutral		Successful

3. How attractive was Interface X?

1	2	3	4	5
Very Unattractive		Neutral		Very Attractive

Appendix H

Post-task questionnaire (Interface Y)

1. How difficult/easy was it for you to perform this task on Interface Y?

○	○	○	○	○
1	2	3	4	5
Very Difficult		Neutral		Very Easy

2. How would you rate your performance using Interface Y?

○	○	○	○	○
1	2	3	4	5
Not Successful		Neutral		Successful

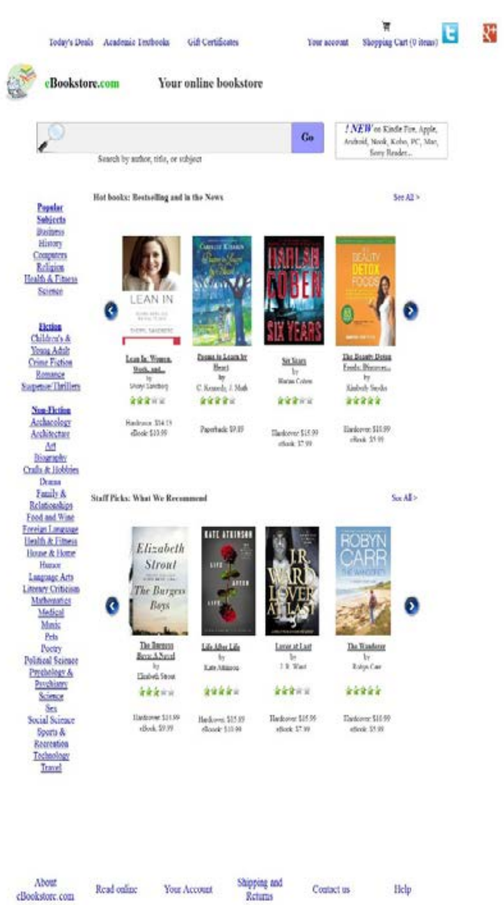
3. How attractive was the user Interface Y?

○	○	○	○	○
1	2	3	4	5
Very Unattractive	Unattractive	Neutral	Attractive	Very Attractive

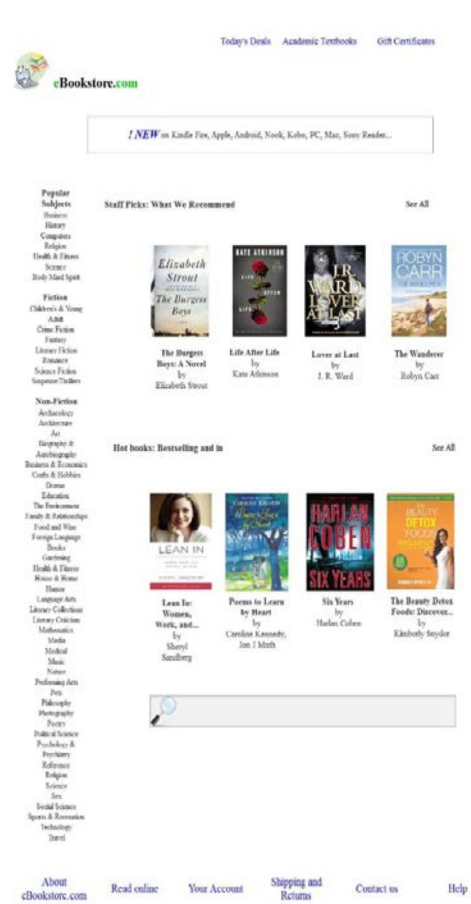
Appendix I

Preference task screen

INTERFACE X



INTERFACE Y



Appendix J

Preference survey

1. Regarding your shopping experience today, which interface was more attractive? Why?
   - Interface X
   - Interface Y

Please explain here:

---

2. Which interface was easier to navigate through? Why?
   - Interface X
   - Interface Y

Please explain here:

---

3. Which of the two interfaces will you be more likely to use in the future? Why?
   - Interface X
   - Interface Y

Please explain here:

Appendix K

Summary of participants' free responses

Question 1: Which interface was more attractive? Why?

Interface	Response	S-R-K level
Y	I thought the minimalistic design of interface y was more attractive, although I found it more difficult to use as it wasn't always clear where to click.	K
X	I like the search box better at the top of the page. Product page also had easier to find buy button.	S
X	I think the most important difference was that Interface X had the search bar at the top of the page.	S
X	Checkout process may be clearer.	R
X	The search bar was in more logical location.	S
X	The interface is clearer in terms of what is click-able and what is not. An interface that clearly indicates the navigation system through its website is an attractive system in itself.	S
X	List to the right served more function as hyperlinks. The checkout page suggested more items.	S, R
X	I think the interface X is more attractive because there is search box at the more optimal position for searching.	S
X	The buttons were clearly marked. The search function was at the top of the page. The jargon used was more applicable to what I was doing (enter vs. checkout).	S, R
X	It was easier to search for the book.	S
X	I preferred Interface X because of the distinctiveness of the search bars (which were my first choice to use when searching), the highlighting of links to the left in blue instead of regular black text, and because some buttons were better defined in X as opposed to Y where some buttons were just black text on a white background with no borders or shapes.	S
X	It's not much more attractive visually. But it is attractive in the sense of it is much more usable.	S
X	The first interface had more visual features that let me know what action they would perform.	S
X	Interface X had more colored icons and links to help me find what I was looking for. Checkout, buy, etc.	S, R

Question 1 (continued)

Interface	Response	S-R-K level
X	Interface X was more attractive to me because the search was on top and the item I was looking for came up instantly when I used the search. I also felt that checking out was faster than interface Y. I also liked that information I cared about was on top versus Interface Y.	S, R
X	It was easier to find the relevant information through the search feature.	S
X	Easier search function. The links provide positive affordances.	S
X	Quicker access to the search bar.	S
X	It was easier to find the search bar (it was right on top).	S
X	Information/genres were easier to pick (Genres were hyperlinks to separate pages). Menus were clear and well organized. The text boxes to be used (e.g., the search bar, the go button, etc.) were bolded and in different colored boxes which made them stand out.	S
Y	It had a more attractive (minimalist) layout yet the search was the most difficult part.	K
X	It had better use of color for links, and had a more appealing proportions.	S
X	It had a better grouping style which made it easier to locate and find content. It used more color that contributed to the aesthetics as well. However, it was still pretty plain (but simple) compared to exciting websites today.	S, R
X	I liked this interface better because it simply had the items I was looking for jump out at me. Buttons were easier to push.	S
X	Had better interaction design, visual design and also was easy to navigate.	S
X	Search bar is easier to find in Interface X, ultimately making it more usable.	S
X	It was more attractive because of the right sidebar navigation menu links and the search field at the top.	S
X	The search bar was more immediately accessible.	S
X	The search bar is clear and right in front. The second is the side options have a under bar and use different color. This can help tell the difference between options and text.	S, R
X	The search bar was at the top and the buttons were highlighted. Naming conventions did not change throughout the checkout process.	S, R

Question 1 (continued)

Interface	Response	S-R-K level
X	More Books. Colors stood out more and I was attracted to that.	S, R
X	I liked the placement of the search widget as well as the checkout experience.	S, R
X	Although a little unattractive, interface X had a more intuitive flow. It was less obvious where to begin in interface Y, and the names of the books were blue and underlined, which typically conveys that the text is a link, and it wasn't clickable. Also, the buttons on the bottom to continue during the checkout process were titled "Enter" and that doesn't quite make sense to me. Continue seems like better terminology. Overall, the content on interface X is more direct to the shopping experience.	S, R
X	They were really about the same in attractiveness, but X was more usable.	S
X	I know what I was looking for and the search bar is at the top. I also liked the easier purchasing method in X. It was easier to add something to the cart.	S, R
X	Search bar was on top.	S
X	The next and back buttons on the rows of books gave it a more polished look. The search bar at the top was a cleaner, easier-to-use look. Hyperlinks on the left looked like hyperlinks.	S, R
X	I rate attractiveness on functionality not on aesthetics. Interface X was more usable for me because of the visibility of the search bar.	S
X	Search bar at the top is nice. Also, the additional indicators at the top right were nice.	S, R
X	It made it more obvious what I should click on and where I should click on things!	S
X	I thought the first one felt current, and the second one felt like a mom and pop shop stuck in the 90's.	S
X	It had a search bar at the top of the page. It used the more traditional shopping cart at the top right side of the page.	S, R
X	Because it was much clearer where the controls were (due to proper salience and conformance to expectations regarding the color and format of hyperlinks), also the search box was where it was expected.	S, R

Question 2: Which interface was easier to use? Why?

Interface	Response	S-R-K level
X	Easier to find buttons and search box.	S
X	The clear hyperlinks and buttons made interface x easier to navigate.	S
X	Interface X had more consistent navigation links and buttons.	S
X	Search box is on the top of the screen. Buttons are clear. Checkout process is more similar to what I used before.	S, R
X	Fewer pages to navigate and the search bar were easier to find.	S
X	What was clickable and what was not was clearly indicated.	S
X	Less clicks and pages.	S
X	Because it offers very clear navigation tips and search box is on the top level position.	S
X	Search function was on top. Fits' law - the checkout and proceed buttons were closer as well.	S, R
X	Searching was on top and easy to access.	S
X	It provided more direction for me as I was proceeding and had a more intuitive navigation pattern.	S, R
X	It had the search bar at the top of the page.	S
X	The buttons worked better at letting me know which to click on versus using text only.	S
X	The colored buttons helped me find my way.	S
X	It was easier because my results were right there.	S
X	I was able to search for book.	S
X	The search bar appeared right on top of the front page.	S
X	Easier access to the search bar.	S
X	The flow was more direct into the search I was going into.	S
X	Everything is presented to you clearly at the very beginning.	S
X	Interface X had a better grouping structure than Y. The search bar was present at the top of the page which is the first place a customer will go to search for products.	S
X	It seemed to be significantly faster.	S
X	The search bar was on top....makes life a lot easier.	S
X	Search bar was prominent. Author name was clickable. Fewer clicks required overall.	S
X	It was easier because of the right sidebar navigation links and the search field at the top.	R, S
X	Naming conventions did not differ and buttons were highlighted better.	R

Question 2 (continued)

Interface	Responses	S-R-K level
X	Search, which is always my primary task, is highest.	S
X	Information was more directly presented.	S, R
X	Easier to find search. Didn’t require me to create an account to make a purchase.	S, R
X	Search bar at the top. Easy buttons to add to the cart.	S, R
X	It was easier to find my "cart" to checkout. Hyperlinks on the left looked like they were "clickable".	S
X	It was clearer where to go and what to click on.	S
X	The product that I needed was available at a sooner time.	S, R
X	It used the more traditional shopping cart at the top right side of the page, which is familiar to most, as it is seen on most shopping websites.	S, R
X	Primarily because of proper conformance to expectations of how an online shopping site should be laid out, with search at the top, and also because all the hyperlinks were blue and underline. Also, I think that the controls were larger. Buttons were different color than the background.	S, R

Question 3: Which of the two interfaces will you be more likely to use in the future? Why?

Interface	Response	S-R-K level
X	Although interface y is more attractive, I would use the more functional interface that was quicker and easier to navigate.	S
X	Easier to navigate and less ugly.	S
X	Easier and faster to use.	S
X	It is more affordable than the other.	S
X	The experience seemed faster.	S
X	For the search function, I will choose interface X because it’s more attractive and the process is easy to checkout.	S, R
X	It has a better usability.	S
X	It had the search bar at the top of the page and the checkout process was much faster and had less steps.	S
X	More physical representations to the interface and better visual flow.	S
X	I felt I did better and I had to do fewer steps.	S
X	Better navigation.	S
X	I need to be able to search... I shouldn’t have to guess where I should look for info....	S, R
X	I think I found success faster using Interface X.	S