POLITECNICO DI TORINO

Master of Science in Management Engineering

Master's Degree Thesis

The evolution of affordance in digital artefacts: a case study on a music CD and music streaming services

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A mia mamma e mio papà, l'ancora di salvezza
della mia vita;
A mia sorella, l'esempio che seguo da sempre;
Ad Antonio, la persona più genuina, generosa e sincera
che potessi incontrare, in grado di tenermi per mano
anche quando lontano;
A Marco, per esserci stato nei momenti felici e
per avermi sorretta in quelli più bui;
A Giuseppe, Anna, Susanna, i miei amici di sempre,
i miei amici per la vita;
A Beatrice, Eleonora, Benedetta, per essermi
silenziosamente rimaste accanto sempre;
A Siliva, perché le vere amicizie ritornano sempre.
Ai legami profondi e duraturi, a quelli che restano per l'eternità.

Abstract

In the last decades, the concept of artefact has faced a great evolution since digitization has led to the need of a categorization of artefacts that could properly include digital products and digital services, which, differently from traditional artefacts, also include a digital component.

Affordance, born in the 70's, has often been characterized by ambiguity and confusion in the literature. One of the main reasons are the countless definitions provided over the years.
Despite being relatively new concepts, the notions of affordance and digital affordance can be used to define a new approach to the design process.

Affordances in a digital system are multiple and connected. They can be classified into two categories: *sensory affordances* and *experiential affordances*. The former arise through sensory perceptions, manifesting themselves before an action is undertaken and suggesting to the actor which action to undertake. Instead, the latter arise during the artefact's usage and can intervene in future actions.

The present work starts with a literature review and summarizes the previous works on the topic. Starting from the concepts of artefacts and their classification, we derived the concept of digital affordance.

The thesis work aims to validate the previously defined model for the design of digital artefacts using affordances, trying to analyze how the model can be applied to different categories of artefacts.
In particular, the validation is performed through the application of the model to a case study that compares two different artefacts: digital products, represented by music CDs and digital services, represented by Streaming Services. The analysis aims to understand whether the categories used to categorize affordance indicators can be uniquely associated with one of the two clusters of affordances: sensory or experiential.
Furthermore, it is also analyzed how the presence of experiential and sensory affordances changes when dealing with different types of digital artefacts.

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1 Introduction

1.1 The problem

An *affordance* was defined by Gibson (1977) as "the perception of the relationship established between a user and an object within an environment".
Norman (1988), by studying affordances in the field of engineering design, stated that, by analyzing the affordances transmitted by an object to the observer, it is possible to define a system architecture that allows the user to interact with the artefact.

Nowadays, designers have to face increasingly difficult challenges brought by *digital artefacts* and their peculiar characteristics. They are indeed characterized by unique properties, that differentiate them from traditional non-digital artefacts: given the generativity nature and the layered modular architecture, they are interactive, re-programmable, editable and distributed.

The re-programmable nature of digital artefacts, allowing quick and inexpensive changes, leads to profound changes in their development process, promoting new points of view to support their design process, one of which based on the concept of affordance. The theoretical basis of the affordance concept seems indeed to have the potential to support the design process of new digital artefacts and the digital systems they enable (Litern, 2010).
Nevertheless, despite the growing interest for the field, literature on the subject is still scarce and ambiguous and it has not been found yet a formalization of the relationship between affordances and digital artefacts nor a methodology for the evaluation of the affordances that characterize them.

Only in recent years there has been an increasing interest from authors towards the definition of formal approaches to the development process based on the concept of affordance. The starting point was the work of Maier and Fadel (2003), although it lacked a formal definition of users and of their needs.

Cormier, in 2014, proposed a new model trying to solve these problems, clearly defining the relationship between users, artefacts and affordances, based on the notion of desired affordances, which could be seen as an abstraction of users' needs.
Also Kim and Hong (2012) proposed a model of interaction with products and services based on affordances and affordance features, to be used for the design of products and services.

Previous thesis works aimed at formalizing an approach for the design of digital artefacts by exploiting affordances. For this reason, it was necessary to conceptualize the notion of *digital affordance*, derived from the intersection between the properties of digital artefacts and the notion of affordance in HCI literature.
Nevertheless, the conceptualization of digital affordance was derived by literature referring to affordance associated with physical artefacts, which are different from digital ones.

1.2 Aim of this work

The goal of this work was to support research in the introduction of a modern point of view to support the development process of digital artefacts, based on the notion of affordance.

The research focused on the analysis of the literature regarding the concepts of *digital artefact* and *affordance* and on the definitions of *digital affordance* provided in precedent thesis works.
The work aimed at comparing two digital artefacts, a digital product and a digital service, to analyze analogies and differences in the affordances that characterized them. The comparison focused on the distinction between sensory and experiential affordances, to investigate whether, shifting from products to services, the amount of affordances belonging to the two clusters changed.

1.3 Methodology

The work started with an analysis of the literature regarding the concept of *artefact*, with a focus on properties and characteristics of *digital artefacts*, and the concept of *affordance*, analyzing the definitions of *digital affordance* given in precedent works.

This research has been followed by the analysis of the case studies examined in precedent thesis works. The aim was to find a pattern in the categorization of affordance indicators from which affordances perception arise.

Subsequently, the work focused on a case study in the music industry. The case study compared a digital product, represented by a music CD and a digital service, represented by a music Streaming Service.
The study focused on the validation of the previously defined model for the analysis of affordances in digital artefacts (Perpignano, 2020). This model defined 9 steps to be followed to identify and evaluate affordances in a digital artefact. It applied the methodology proposed by Maier (2009), that is the identification of affordances by studying the functional nature of the system, and the one proposed in (Chenyi Chen, 2015) for the analysis of affordances based on key affordance indicators.
In particular, it has been chosen to evaluate affordances starting from affordance indicators in order to reduce the complexity of affordances evaluation. It has been therefore asked to users to express their opinion on the perception of the usability of the indicators from which the perceptions of the affordance originate.

The validation has been performed through the administration of a questionnaire to artefacts' users, with the objective of understanding whether the categories used to classify affordance indicators could be uniquely associated with one of the two clusters of affordances: sensory or experiential. Sensory affordances arise through sensory perceptions, manifesting themselves before an action is undertaken and suggesting to the actor which action to undertake.
Experiential affordances, instead, arise during the artefact's usage and can intervene in future actions.
This analysis has been followed by the evaluation of the affordances that characterize the two artefacts, to investigate whether, in different types of digital artefacts, one of the two clusters of affordances, sensory or experiential, prevailed.

1.4 Structure of this document

This document is made up of 5 chapters:

Chapter 1 is the Introduction chapter, providing insights on the initial problem, the aim of the work and the methodology used for its achievement.

Chapter 2 is devoted to the review of the literature regarding the definition of digital artefacts, the main characteristics that distinguish them from traditional ones and the analysis of artefacts classification. Given the growing complexity of digital artefacts, a new approach to their design is analyzed and in particular the concept of Human-Centered design, focusing on the model of User Experience defined by Pucillo and Cascini (2014).

Chapter 3 starts with a literature review on the concept of affordance, focusing on the definition in Human-Computer Interaction and the application in the engineering design field. The chapter continues with the analysis of the definition of digital affordances and of the methodology for their evaluation in digital artefacts.

Chapter 4 is focused on the evaluation of a case study that compares a digital product and a digital service, to investigate whether the different categories (Roskos, 2017) and dimensions (Shao, 2020) used to describe a digital system, can be uniquely associated to one cluster of affordances (sensory or experiential), and whether one of the two clusters prevails in different types of digital artefacts.

Chapter 5 contains the main conclusions and limitations of the work.

2 Digital Artefacts and Artefacts Classification

Digitization has led to new competitive dynamics and towards the need of a new theoretical framework for competitive strategy and for the development of digitized products.
Digital technologies has indeed become one of the main sources for innovation (Lyytinen & Yoo, 2002), with a growing number of physical artefacts completed by digital components or completely replaced by digital artefacts, leading to valuable changes between digital and non-digital artefacts, also for their design process (Cantamessa et al., 2020).

2.1 Digital Artefacts

To understand how the design process of artefacts is modified by the advent of digitization it is important to clarify the concept of digital artefact and analyze how it differs from the traditional non-digital one.

In precedent literature, digital artefacts have been defined referring to digital infrastructures, digital platforms or digital artefacts in general (Eck, 2015) .

2.1.1 Digital infrastructure

Digital infrastructures are defined as networked systems that goes beyond individual organizations and may gain global reach (Ciborra, 2000).
They are then defined by Hanseth & Lyytinen (2010) as a shared, open and evolving socio-technical system composed of other infrastructures, platforms, application and IT capabilities. The openness that characterizes them, for which there are no boundaries between those that can design it and those that may not, implies that the social and technical diversity and heterogeneity of digital infrastructures will increase during their lifetime.

2.1.2 Digital platform

Hanseth & Lyytinen (2010) also define the concept of digital platforms, as an organization of IT capabilities into frameworks, allowing the software to address a family of generic functional specifications that meet the needs of multiple, heterogeneous and growing user communities.
The complexity of platforms typically grows as designers take into account heterogeneous user needs while maintaining backward compatibility and horizontal compatibility across different combinations of capabilities. For this reason, many platforms obtain later emergent features, serving unexpected users and generating exponentially growing technical and social complexity.

The difference between a digital platform and a digital infrastructure stands in the number of actors that control it. The former is controlled by a single actor, while the latter's control is distributed across many actors.

2.1.3 Digital Artefact

There is not a widely accepted definition of digital artefact, and indeed it has been argued that this term is useful at all (Alter, 2015).

Faulkner (2010) defines three criteria that characterize a non-material technological object:

1. It is an *Object*: characterized by endurance and structure.
2. It is a *Technological Object*: object to which human beings have assigned uses in order to pursue their practical interests.
3. It has *Non-material mode of being*.

He also made a distinction between the non-material technological object and its *bearer*, media on which it is stored and through which it is accessed and communicated, that can be a non-material object too.

According to Faulkner (2010), non-material objects have three main properties:

1. *Non-rivalry in use*: its use by a person does not affect its simultaneous use by others.
2. *Expansibility*: ease with which additional material bearers can be made available to potential users.

3. *Recombinability*: ease with which an object can be combined with others in order to generate new kinds of objects.

Kallinikos (2013) then describes digital artefacts as intentionally incomplete (Garud et al., 2008; Zittrain) and lacking a clear identity because of the constant change they undergo (Ekbia, 2009).
This incompleteness has both positive and negative aspects. On one hand, it does not preclude the range of tasks and operational links the digital artefact can perform; on the other hand, it leads to a reduction of the control over the artefact and over its use.
A digital artefact is on one hand an object, but on the other hand it lacks the stability afforded by traditional items and devices, and this is why it is better seen as a quasi-object (Ekbia, 2009): this is why it is said that digital artefacts have an ambivalent ontology.
Those artefacts, by resisting easy change, can be sticky and unresponsive, entailing lock-in and path-dependent evolutionary trajectories (Ciborra, 2000).

Combining the discussion of technology concept (Orlikowski, 1992) with the conceptualization of distinct digital artefact attributes (Kallinikos, 2013), according to Eck (2015) a digital artefact can be defined as an object created by and composed of digital technology. It is created and changed by human actors, but it is also used by them in order to accomplish some actions. It fundamentally differs from a physical artefact given that it is interactive, editable, re-programmable, distributed, modular, granular, and reflexive.

2.2 Characteristics of Digital Artefacts

Digital artefacts, thanks to their peculiar properties, are highly generative. Generativity is defined in (Zittrain, 2006) as a technology's overall capacity to produce unprompted change driven by large, varied, and uncoordinated audiences. This nature confers the digital artefact important properties, such as being one of the dominant sources for innovation.

Generativity is a function of four main properties of a given technology:

- *Capacity for leverage*: extent to which the object enables valuable accomplishments that otherwise would be either impossible, either not worth the effort to achieve.
- *Adaptability*: extent to which a technology can be used without change and the readiness with which it might be modified.

- *Ease of mastery*: ease with which people can adopt and adapt it.
- *Accessibility*: ease with which the technology can be readily seen and controlled by people.

Digital artefacts differ greatly from physical entities along a number of dimensions, leading to fundamental transformations in their development and use. From (Eck, 2015) and (Kallinikos, 2010) , it is possible to highlight four main characteristics of digital artefacts:

1. *Interactivity*: defines the possibility to explore a digital artefact, its individual components and dependencies, offering different pathways along which users can activate the functions embedded in the object or explore the arrangement of the information items. Differently from editability, it does not produce any modification of the digital object.
2. *Editability*: relates to the possibility to modify or update the artefact continuously and systematically, while leaving its logical structure unchanged. It can be achieved by just rearranging the elements of which a digital object is composed, by deleting existing elements or adding new ones, or even by modifying some of the functions of individual elements. In other cases, it is built into the object in the form of regular or continuous updating of content or items.
3. *Reprogrammability*: relates to the possibility to access and modify the digital artefact by a program, releasing the artefact from its immediate use context.
4. *Distributedness*: means that digital artefacts are not contained within a single source or institution, but they are distributed.

Beside these, there are three corollary attributes:

1. *Modularity*: refers to the quality of modularized digital artefacts, which allows for independence and do not bound to a fixed product architecture. This means that the individual modules of a complex digital artefact can be transferred to completely unrelated use contexts.
2. *Granularity*: refers to the inherent decomposability of digital artefacts, down to their binary representation, and the possibility to modify a part, both insignificant and substantial, of the artefact on different levels of abstraction. While modularity concerns the relationships between blocks, granularity consider the parts of which these blocks are made.

3. *Reflexive dynamics*: means that any access, assembly, or otherwise manipulation can only be performed through making use of other digital artefacts. Consequently, any domain with digital artefacts will see an increase of the digital artefacts over time.

Based on these, a new definition of digital artefact is provided on the thesis work of (Perpignano, 2020):

"A digital artefact is any object material or immaterial, based on a digital technology allowing: collection, processing and/or transmission of structured data. The artefact has qualities such as Editability, Interactivity, Reprogrammability, Distributedness" .

This definition does not only take into account non-material objects, but it includes also physical artefacts, allowing the interaction with the non-material nature of the digital artefact.

2.3 Layered Modular Architecture

Digital innovation can be defined as the carrying out of new combination of digital and physical components to produce novel products, or as the enhancing of physical products by means of digital capabilities (Yoo, 2010).

One critical success factor of digital innovation is the development of a new type of architecture: the *layered modular architecture*. It extends the modular architecture of physical products by incorporating four different layers created by digital technology, integrating physical and digital components in order to produce novel products.

Digital innovation generative potential is indeed expressed by a *layered architecture* that separate the material aspects of digital artefacts (e.g. hardware) from the non-material ones (e.g. software and data) (Schultze, 2013).

This new architecture is a hybrid between two different architectures:

- **Layered Architecture of digital technology**:
  It consists of four different layers: device layer, network layer, service layer and contents layer. These layers represent different design hierarchies, highlighting the hierarchically dependence between the hardware, software and data elements in a digital artefact. Its main purpose is to add the generativity.

Upper layers (immaterial/logical) are becoming increasingly independent from the lower ones (material/physical) and they start to dominate them, leading to a shift of powers.

- **Modular Architecture of physical products**:
  It is characterized by functional independence between components, with a one-to-one mapping between functional elements and physical modules (Ulrich, 1995).
  This product architecture decomposes the product into loosely coupled components, which are interconnected through prespecified interfaces, leading to a reduction of the complexity and an increase of the flexibility in design (Baldwin and Clark, 2000).

In the modular architecture the *product boundary is fixed*: the modular design is given by the decomposition of the product into components, based on the functional design hierarchy (Clark, 1985; Baldwin and Clark, 2000). Therefore, the relationship between the product and its components is nested and fixed. The design of components is driven by the functional requirements of a given product; so, even if certain low-level components can be used in multiple products, they can be considered as *product-specifics*.

In case of the layered modular architecture, instead, the boundary at product level is *not fixed*, requiring little product-specific knowledge for design. For this reason, components can be considered as *product-agnostic*.

In case of modular architecture, the main goal is the increase of flexibility, which can be reached by substituting components within a single hierarchy. So, flexibility comes from *differences in degree*.
For the layered modular architecture, instead, the design of the product depends on an ensemble of components coming from heterogeneous layers, each belonging to a different design hierarchy (Clark, 1985). As such, this architecture offers generativity, accomplished through loose coupling across layers, where innovation can arise independently at any layer, leading to a cascading effect on the other layers, thus producing *differences in kind*.

The modular layered architecture can be described as in Figure 2.1, considering an orthogonal relationship (Lee and Berente, 2012) between the digital control system hierarchy, or layered architecture, and the physical product hierarchy, or modular architecture.
This figure highlights how digital products connect to different parts of the physical product hierarchy, integrating functionality and data from traditionally separate components.

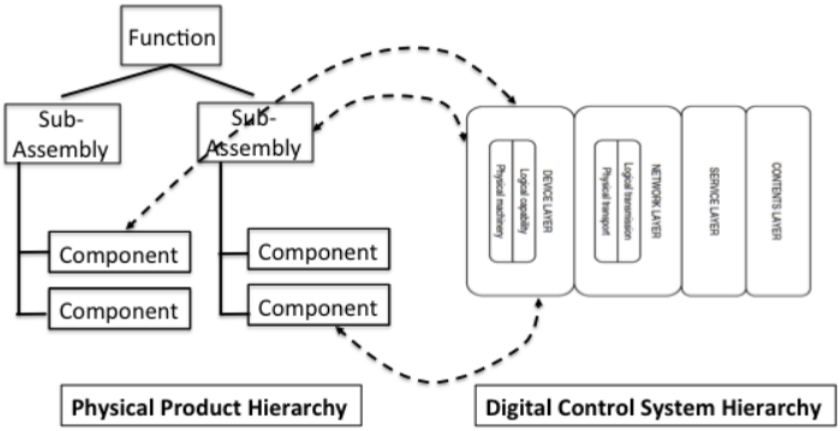


Figure 2.1: Scheme of the modular layered architecture (Schultze, 2013).

The orthogonal relationship is then reflected in the organization' social structure. This new architecture, indeed, leads to profound changes in the ways firms organize for innovation.

2.4 Human-centered design

Interactive artefacts are becoming more and more complex day by day, with new technologies, applications, and methods of interaction that continuously arise and evolve. The main problem is that each update requires time before it can adopt the principle of good design. A possible solution to this problem can be the Human-Centered Design (HCD), defined by Norman (2013) as an approach that puts human needs, capabilities and behaviors first, designing in order to accommodate them. The starting point is indeed a good understanding of people.
The design of an interactive artefact is the design of behaviors and experiences, so it must address the whole *User experience (UX)*. The UX is defined in the ISO 9241-210 as "a consequence of the presentation, functionality, system performance, interactive behaviour, and assistive capabilities of an interactive system, both hardware and software. It is also a consequence of the user's prior experiences, attitudes, skills, habits and personality".

Pucillo and Cascini (2014) developed a model of UX to be used as a prescriptive foundation of the design for the UX, avoiding the imposition of experiences to the user. This model is based on the one proposed by Hassenzahl (2010),

adding the notion of affordance.
According to the Hassenzahl model, goals can be classified in a three level hierarchical organization:

1. *Motor-goals*: goals related to single basic actions undertaken by the user.
2. *Do-goals*: higher level of goals, reached through an action plan, set of basic actions and the effects they generate.
3. *Be-goals*: highest level of goals, associated with the degree of satisfaction with which the starting need is satisfied.

The idea of Pucillo and Cascini (2014) is to explain how perceptions that allow users to undertake a series of actions and to escalate the three hierarchical level of goals arise, through the hierarchization of the objectives (Carver and Scheier, 1998).

Since affordances are possibilities for actions, it is possible to define different types of affordances associated to different types of actions (Figure 2.2):

Affordance	*Goal to be achieved by the user*	*Information/disposition needed to perceive it*	*Example*
Experience affordance	Be-goal	Right usage mode	Be closer to a distant person
Use affordance	Do-goal	Mental models; use plan	Send a text message
Effect affordance		Capability of correlating cause and effect; optionally, functioning of parts, cultural symbols	Type letters, move a slider across a menu...
Manipulation affordance	Motor-goal	Perceptual info	Press a button, move a finger on a touchscreen

Figure 2.2: Description of the affordances' levels (Pucillo and Cascini, 2014).

- *Manipulation affordance*: associated to the basic actions.
- *Effect affordance*: associated to the effects generated by the basic actions.
- *Use affordance*: associated to the action plans.
- *Experience affordance*: associated to the Be-Goal level.

Following this characterization of affordances, the Hassenzahl's model can be adapted, in order to express the relationship among users and objects in terms of affordances, as shown in Figure 2.3.

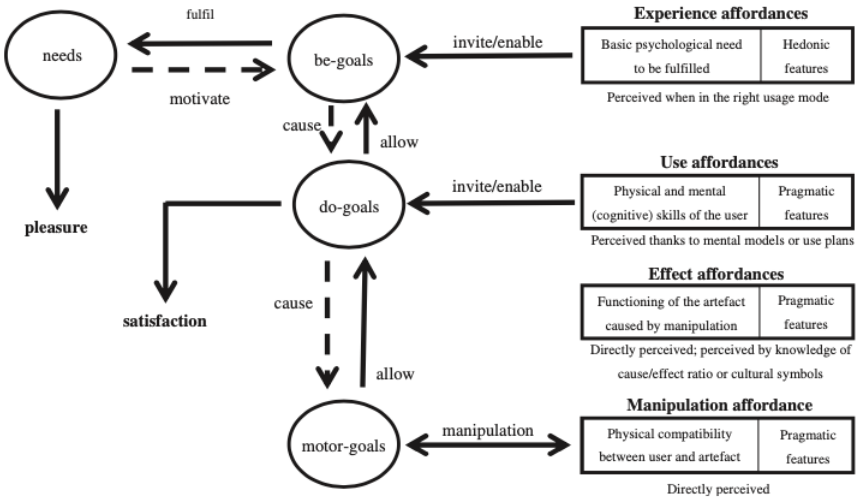


Figure 2.3: Framework for UX design based on affordances, explaining how the three goals' levels can be reached through affordances (Pucillo and Cascini, 2014).

This model can be used by designers to design interactive artefacts, in order to design for experience, leaving the necessary room for users' interpretation, and avoiding to force them into the experience. In particular, by reasoning in terms of affordances, that can be seen as invitations, designers can express their own proposal, which can even be refused by users.

2.5 Artefacts classification

Large part of the precedent thesis work of (Tiotto, 2022) was focused on the classification of artefacts, starting from a review of the concepts of product and service.

According to this work, artefacts can be classified in six categories, defined as follows:

- *Non-digital product*:

  "Purely material object with the function of satisfying or anticipating users needs. It derives from a standardized production process that occurs prior the consumption of the product itself and which gives it the characteristic of homogeneity. Furthermore, it can be stored and is saleable/marketable".

- *Non-digital PSS (Product Service System)*:

  "Non-digital product through which a service can be provided. While the material object constituting the product derives from a standardized production process and can be stored, the performance derives from a customized process, unique and simultaneous to consumption. Furthermore, the service is saleable/marketable but it cannot be stored".

- *Non-digital service*:

  "Intangible performance with the function of satisfying or anticipating users needs. Its realization takes place through customized and unique processes that give the service the characteristic of heterogeneity; in addition, it provides an interaction with the user and simultaneous consumption of the same. It does not use any physical or digital device to be dispensed, sold or delivered and it cannot be stored".

- *Digital product*:

  "Tangible object with an intangible component (bitstring) with which it is possible to store, transmit or transfer information. It therefore has a dual function: to satisfy or anticipate users needs and to allow the exchange of information. It derives from a standardized production process which, only for the physical component, occurs prior to the consumption of the product itself. The immaterial/digital component can be instead copied, recombined or modified even later.
  It is an "experience-good" capable of interacting with other objects, with

humans and with the surrounding environment. Finally, it can be stored and is saleable/marketable".

- *Digital PSS (Product Service System)*:

  "Digital product that provides the provision of an intangible service (through the physical device). While the physical component derives from a standardized production process and can be stored, the performance derives from a customized process, unique and simultaneous to consumption. Furthermore, the service is saleable/marketable but it cannot be stored".

  Given that the characteristics of a digital product and of a digital PSS are the same, with the exception that the immaterial component of the PSS is characterized by a performance, they can be grouped into a single category called Cyber Physical System (CPS).
  The concept of CPS has been introduced in recent years, as a new generation of systems capable of expanding the capabilities of the physical world towards computation, communication and control (Baheti and Gill, 2011). It has also been defined as a system connecting physical and digital world (Lee, 2015).

- *Digital service*:

  "Intangible service in the form of bitstring which is not provided by a physical device an which has the dual function of satisfying or anticipating customers needs and allowing the exchange of information. It derives from a customized process, unique and simultaneous to consumption; it is saleable/marketable but it cannot be stored.

  It is an "experience-good" able to interact with the user, the external environment and other digital devices and allows the storage, transmission and transfer of information".

After this classification, a new definition of digital artefact is provided (Tiotto, 2022):

"A digital artefact is the set of an intangible component (bitstring) and a material one (means or bearer) which can be stored and allows the storage, transmission and transfer of the information contained in the intangible component; it also has the function of satisfying or anticipating customer needs.

The "double nature" of this type of artefact gives it the following characteristics: non-rivalry in consumption, non-excludibility, durability over time, being able to be copied without excessive cost or effort, multifunctionality and recombinability.
It is also an "experience-good" with commercial value (it is saleable/marketable) and is able to interact with other objects, with humans and the surrounding environment".

The classification of artefacts can be represented through a Cartesian diagram as in Figure 2.4. Taking this classification into account is fundamental when thinking about artefacts design and the related affordances, given that the latter can change when considering different artefacts.

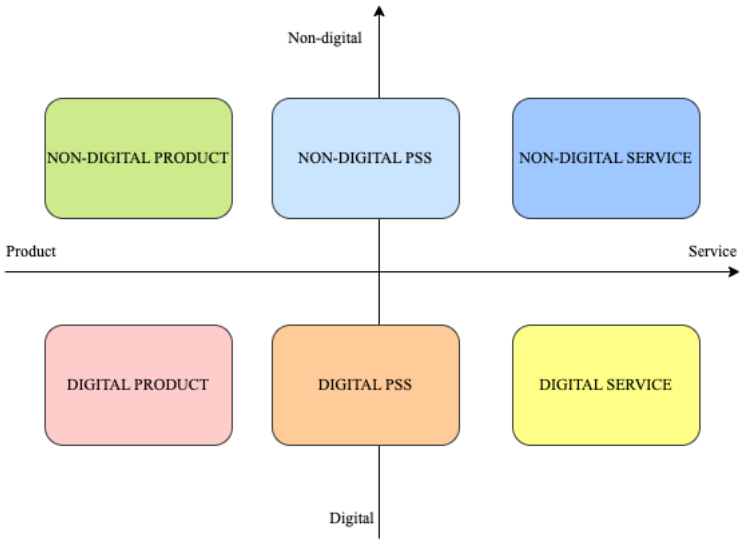


Figure 2.4: Representation of artefacts' classification.

3 Affordance and Digital Affordance

Digitization and the diffusion of digital artefacts, which are becoming more and more complex day by day, lead to major changes in the development process of artefacts, requiring new approaches for their design.
Given that users' behavior and the interaction between the user and the artefact are strongly influenced by the nature of the artefact itself (Norman, 1988), the concept of affordance seems to be adequate for the development of a new approach for artefacts' design.

3.1 Affordance

The term affordance was coined by the psychologist J. Gibson in 1979, to explain how animals, considered as actors, were able to grasp the intrinsic meaning of an object without resorting any type of reasoning, but simply by sensory perception, defined by Gibson as *affordance*.
Gibson describes affordances of the environment as: "What it offers the animal, what it provides or furnishes, either for good or ill" .

This definition implies a complementarity between the animal and the environment, the animal has to perceive the affordances enabled by some physical features (such as size, surface, material) of the environment.
Affordances can be positive or negative, depending on whether they are beneficial or injurious for the observer, thus they have to be perceived. Nevertheless, affordances exist independently from the observers' perception and do not change as their goals or needs do. According to his needs the observer may or may not perceive the affordance but, being invariant, it is always there to be perceived.
Summing up, the affordance for Gibson represents sensory perceptions of the observer regarding the relationship between her and an object inside the environment.

The term was then used by different authors, among which one of the most relevant is D. Norman (1988), who studied affordances in the field of Engineering Design, allowing to design products which fulfill human needs, while being understandable and usable.
According to Norman the term affordance refers to the relationship between the properties of the object and the capabilities of the agent that determines how the object can be used. They result from the mental interpretation of things, based on our past knowledge and experience applied to our perception of the things about us.

Therefore, Norman defines an affordance as a *relationship*, depending on the properties of both the object and the agent and on his previous knowledge and experience. This is the reason why Norman's definition differ from the one of Gibson: according to Norman, affordances are related to the interpretation of the object and are built on previous experience and knowledge of the user.

It is crucial that affordances are perceived, those a means of signaling their presence is needed: the signaling component of affordances is called by Norman *signifier*. Those, it is the *perceived affordance* rather than the *actual affordance* that influences users behavior (Pols, 2012). The affordance refers to the perceived properties of the thing, that determine how the thing could properly be used.

Gibson and Norman are seen as the fathers of the modern conceptualization of affordance. Starting from their works, in the last 40 years, several authors resumed the concept of affordance, defining it in the most dissimilar ways, not allowing to fully grasp its meaning.

3.2 Affordance in Human Computer Interaction

The definition of the affordance in HCI is given by Gaver (1991), defining affordances as "Properties of the world that make possible some action to an organism equipped to act in a certain way", implying the complementarity between the acting organism and the acted-upon environment.
This definition highlights the essence of affordances, that point to the relationship between the properties of the environment and the possibilities for action it allows.

Starting from this definition, Gaver makes a distinction between affordances and the perceptual information about them (Figure 3.1), allowing to consider

affordances as properties to design and analyze on their own.
Affordances imply the compatibility between the physical attributes of the object and of the actor and the availability of information about these attributes, in a form compatible with a perceptual system: the object's attributes must provide a number of information that can be perceived by the actor.
Therefore, affordances need to be perceived but, despite this, they are independent from perception, they exist whether or not they are perceived.

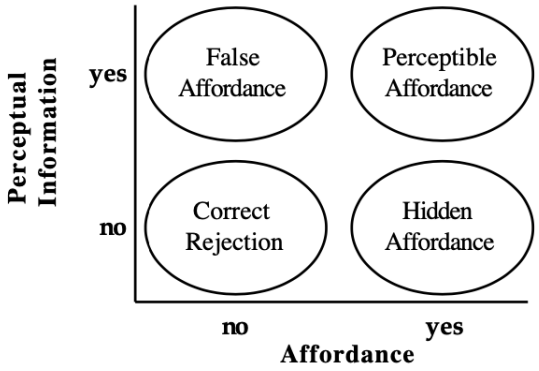


Figure 3.1: Affordance categories according to Gaver (1991).

In order to design a easily-used system a designer must be able to make affordances perceptible, since false or hidden affordances lead to mistakes.

As shown in Figure 3.1, affordance is classified by Gaver in 4 categories:

- **Perceptible affordance**: perceptual information for an existing affordance are available to the user, generating designed stimuli.
- **Hidden affordance**: there is no information available for an existing affordance, preventing the generation of designed stimuli.
- **False affordance**: information suggest a non-existent affordance, and people may mistakenly try to act on this affordance, generating unwanted stimuli by designers.
- **Correct rejection**: there is no affordance and no perceptual information suggesting it.

This distinction highlights the importance of information, or better of the information context, in allowing the identification, interpretation and perception

of affordances.
An important role in the field of HCI is played by interfaces, means that allow the interaction between the user and the digital artefact. Interfaces may offer perceptible affordances since they can offer information about objects which may be acted upon, increasing the importance of the interface design process. Digital artefacts, because of their layered modular architecture, are characterized by hierarchies of functional elements, meaning that multiple affordances can arise from them, leading to the conceptualization of *sequential* and *nested affordance.*

- **Sequential affordance**: an action on a perceptible affordance leads to information indicating new affordances. It describes affordances connected over time.
- **Nested affordance**: it describes affordances grouped in space.

In case of complex systems, therefore, a good interface should provide information related to groups of sequential and nested affordances that characterize them.

3.3 Affordance in engineering design

Affordance-based design theories can represent a valuable analytical basis for the design of system architecture that allows the user to interact with an artefact in the most effective, efficient and satisfactory way, in particular in case of digital-enabled services. However, there is not a specific protocol for the evaluation of affordances in the digital world, since the connection of affordances and digital artefacts has never been fully formalized.

Only in the last twenty years authors begun to formalize approaches to the design process based on the affordance concept. In the following sections three main approaches are illustrated.

3.3.1 Maier and Fadel: affordance-based design

The first model that provides a generalized theory of affordances applicable to the design process comes from Maier and Fadel (2003), who propose a model based on users needs that, once gathered and understood, can be structured as affordances (Figure 3.2) .
An affordance is defined as a *relational concept for design*, enabling to address the interaction between three entities: designers, artefacts and users .

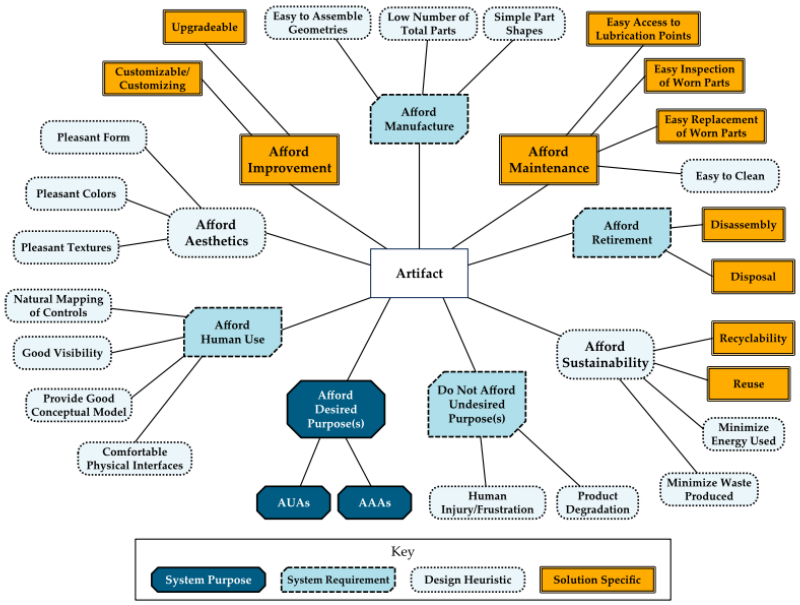


Figure 3.2: Generic affordance structure - from Maier & Fadel (2003).

Maier and Fadel (2003) define two classes of affordance, to which a third one is added by Hu and Fadel (2012), that designers should consider:

- *Artefact-User affordance*: interaction between artefact and user where the properties of the artefact offer a potential use to the user.
- *Artefact-artefact affordance*: potential behavior that may be exhibited only by the two artefacts together, usually designed in order to fulfill artefact-user affordances.
- *Artefact-Environment affordance*: introduced in order to capture any interaction between an artefact and an object that is neither an artefact nor a user.

The definition of users is also extended to include any organism that can intentionally interact with an artefact (Hu & Fadel, 2012).

The interaction between the user and the designer provides the information needed to specify which affordances should and should not exist in the artefact, while the interaction between the designer and the artefact specify the properties of the artefact and allows to determine the affordances both internally (AAA) and externally to the user (AUA), as shown in Figure 3.3.

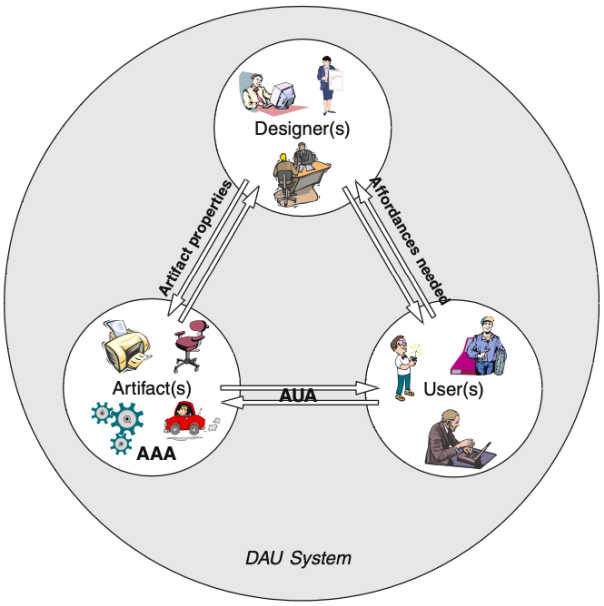


Figure 3.3: Affordance related interactions within a designer-artefact-user system (Maier, 2009).

A major insight is the principle that "structure influences behavior", since the structure of the system determines the enabled affordances and thus describe the possible behaviors.
This affordance-based method offers a different way of thinking to the design process and, starting from it, an affordance-based definition of design can be provided. In particular, design can be seen as the specification of a system structure that possess certain desired affordances in order to support certain desired behaviors, but does not possess certain undesired affordances in order to avoid certain undesired behaviors (Maier, 2009).

Three different kinds of organizations can be used for grouping affordances:

1. *Topological organization*: based on their generic category.

2. *Hierarchical organization*: based on priority level, or importance of the affordance.

3. *User group organization*: based on users who desire each affordance.

Since the first one is the only one characterized by a formal relational structure, it is the one that will actually be used.

Unfortunately this model contains several problems, mainly the lack of identification of users and of the affordances they want the artefact to have, and the unclear vision of how the characteristics of the user and of the operating environment are captured (Cormier, 2014).

3.3.2 Cormier: Desired Affordance model

A possible solution to these problems is the model proposed by Cormier (2014), that can be used in the early stages of the design process, in order to improve model quality and consistency, focusing on problem formalization and abstraction.
According to this model, affordances provided by an artefact are *user and solution dependent*, while *desired affordances*, benefits users desire from an artefact, are *solution independent*. Desired affordances are not inherent to the artefact but they are relational benefits that users hope to gain from an artefact, and can be seen as an abstraction of user needs.

The DAM model is composed of three main elements:

1. **Users**: everyone who interacts with and is temporarily impacted by the principal artefact (the artefact being designed).

   Users possess four main characteristics (Figure 3.4) that change over time and that influence the structure of the artefact needed to provide the desired affordances:

   - *Human Factors*: including relevant anthropometric characteristics and bio-mechanical capabilities.
   - *Knowledge*: including users' capabilities on how they know how to use the product and how well they are able to perform different operations.
   - *Preferences*: referring to subjective aspects of the artefact, such as aesthetic considerations.
   - *Constraints*: referring to factors influencing the required structure of the artefact, not directly related to the user, such as regulations.

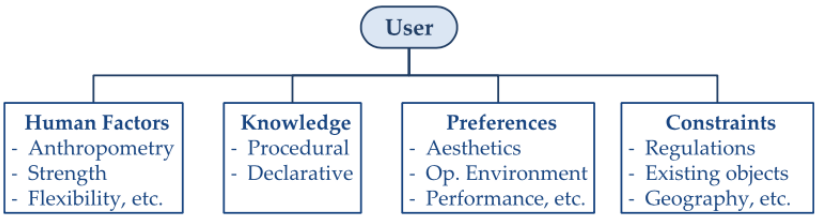


Figure 3.4: User characteristics model according to Cormier' s model.

2. **Artefacts**: all the artefacts interacting with the principal one, which are defined as specific to a user since, according to the model, artefact-artefact affordances exist to benefit a specific user.

   Three main categories of artefacts are identified, considering the type of relationship with the principal artefact:

   - *Support*: artefacts that support the capabilities of another one, by adding or enhancing performance.
   - *Dependent*: artefacts dependent on another one.
   - *Environmental*: artefacts that exist in the same environment of the principal one.

3. **Affordances**: all the artefact-user and artefact-artefact affordances that the principal artefact should provide.

   These affordances can be identified through a formal affordance statement structure: "the principal artefact affords a *[user] [affordance]* of *[target object or environmental entity] [from additional information (optional)]*".

The next step, after the definition of the three elements, is the creation of the relationship tree that captures all the relationships between the principal artefact and the different users and artefacts interacting with it, as shown in Figure 3.5.
This model enables designers to strategically connect the principal artefact, the users and the other artefacts, in order to capture and organize user needs.

The most difficult part of the model creation is the identification of affordances. Several authors have proposed methods to facilitate this step. Maier and Fadel propose to use the Generic Affordance Structure (Figure 3.2) that provides a set of common affordances, as a checklist by designers, to be sure that all the aspects of the affordance have been considered.

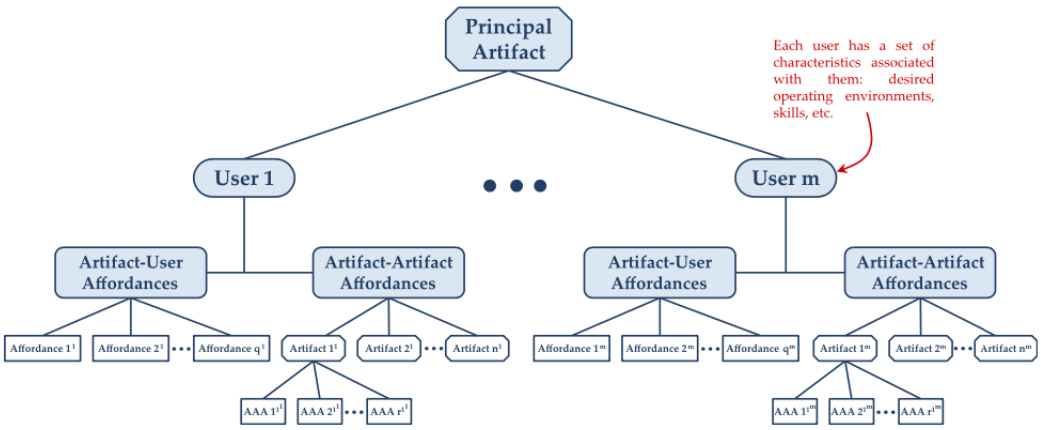


Figure 3.5: Cormier's affordance model structure.

Kim (2015), instead, proposes to design affordances by using *repositories of affordance features*. Starting from a given design problem, a list of affordances is defined. For each affordance, a set of affordance features are selected from the repository, depending on design constraints and context. Finally, a new affordance feature is defined, through analogical reasoning.

According to Cormier (2014) a series of standardized questions can be used in order to facilitate the identification of the different model elements. The lists of questions to be used for the identification of users, artefacts and affordances are reported in Figures 3.6, 3.7 and 3.8 respectively.

User class	Prompt questions
Production	How will the product be manufactured?
	How will the consumer acquire the artifact (i.e., delivered, picked up, etc.)?
Usage	Does the artifact interact with more than one individual at a time?
	Who receives a direct benefit from the artifact?
	Who is the product used around?
	Who cares for, maintains, or monitors the artifact?
	Who is available to assist a user when they have a problem with the artifact?
End of life	How is the product taken out of usage?
	What happens to the product when the user is done with it?

Figure 3.6: Questions for user identification according to Cormier's model.

Artifact category	Prompt questions
Support	What artifacts rely on the principal artifact for inputs?
	What artifacts rely on the principal artifact for control?
	What artifacts rely on the principal artifact for physical augmentation?
	What artifacts use the principal artifact to augment or add functionality?
Dependent	What artifacts does the principal artifact rely on for inputs?
	What artifacts does the principal artifact rely on for control?
	What artifacts does the principal artifact rely on for physical augmentation?
	What artifacts does the principal artifact rely on to augment or add functionality?
Environmental	What artifacts are used alongside the principal artifact toward a larger goal, but do not interact directly with the artifact?
	What artifacts are used before or after the principal artifact in completing a larger task?
	What artifacts are used to prepare the environment?
	What artifacts generate inputs for the principal artifact?
	What artifacts encapsulate the principal artifact?
	What artifacts inhabit (or operate within) the principal artifact?

Figure 3.7: Questions for artefact identification according to Cormier's model.

What type of experience are you trying to provide to the user?
What job or set of jobs will the principal artifact be trying to complete?
What impacts the convenience of performing a job?
What tasks are required to complete the job?
When is the job performed?
Where is the job performed?
What are the relationships between the identified users and artifacts?

Figure 3.8: Questions for affordance identification according to Cormier's model.

3.3.3 Kim-Hong: affordance-based interaction model for products and services

Kim and Hong (2012) propose a model of interaction with products and services based on affordances and affordance features, highlighting the importance of interaction design. This model can be used for the analysis of different product and service designs from a human-centered point of view.

The core of the interaction process is the *activity* performed by the actor. An activity requires three steps: *perception*, *judgment* and *action*.

The context-based activity model is characterized by some important features (Figure 3.9):

- *Action verb*: the core of the activity.
- *Object*: object of the action, it can be a product, a service, or even a combination of the two.

- *User*: subject of the activity.
- *Passive actor/third party actor*: optional additional actors who may be involved in the activity.
- *Environment*: description of the overall environment characteristics.
- *Event*: it points to another activity which motivates the current one.
- *Context field*: defined by the goal context, the relevant structures, the physical context and the psychological context.

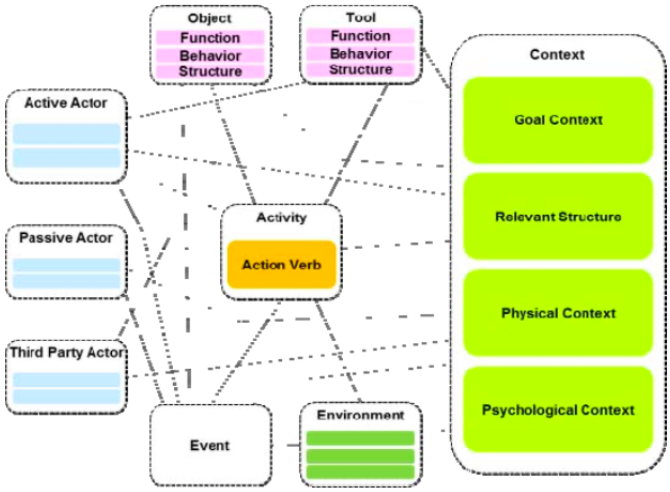


Figure 3.9: Context-based activity modeling according to Kim and Hong's model (2012).

For an activity to be performed, the active actor does the action on the object, using a tool, to the passive actor in the environment, motivated by the event, under the context field (Kim, 2012).

During the interaction process between the human and the product, the product provides messages, or affordances, through structural elements called affordance features, inducing an activity. The interaction is then the effect of three aspects related to the human:

- *User's knowledge*: affordance features induce an activity only to those users who know how to use the product.
- *User's expectation*: affordance features induce an activity only when the level of expectation of the user is high.

- *User's experience value*: affordance features induce an activity if they serve experience value that the user wants to.

As shown in the interaction model between the human and the product (Figure 3.10), users' characteristics (such as demographics, personal attributes) and contextual elements (such as social, cultural, physical environment) influence the interaction as well.
In case of services, the model shows the interaction between the service provider and the service receiver.

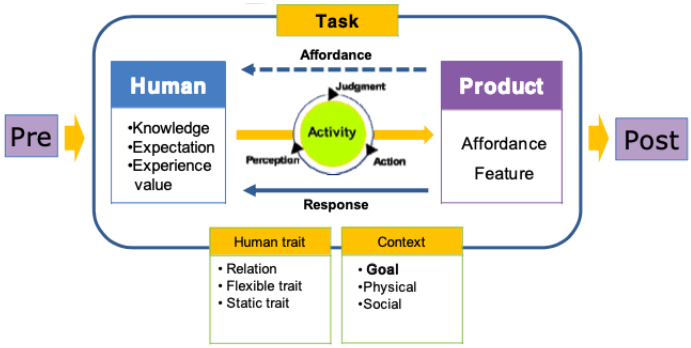


Figure 3.10: Interaction model with products according to Kim and Hong's model (2012).

3.4 Digital Affordance

The traditional affordance concept is not enough to support the design of digital artefacts. A definition of digital affordance is therefore needed and the starting point is the definition of a method to construct the affordance concept.

3.4.1 Methodology for the construction of the digital affordance concept

The methodology to be used for the construction of the digital affordance concept is based on the work of Evans (2017) , who defines a more consistent approach to the conceptualization and application of affordances, based on three criteria:

1. Confirm that the proposed Affordance is neither an Object nor a Feature of the object.

2. Confirm that the proposed Affordance is not an Outcome.

3. Confirm that the proposed Affordance has Variability.

Criteria #1
The affordance does not have to be associated to technology-specific features of the object, but to the relationship between the object and the outcome, in coordination with human goals.
The association with the technological features of the object is often implied by language that talks about the affordances of specific technologies (Gaver, 1991), positioning the affordance as inherent in some material aspects of the technology. However, the affordance does not belong to the environment nor to the individual, but to the relationship between the individual and her perception of the environment (Parchoma, 2014).
Furthermore, while features are *static*, affordances are *dynamic*, since they emerge from the relationship between the user, the object and its features (Leonardi, 2012).

Criteria #2
An affordance promotes different behaviors related to different outcomes, but it is not the outcome itself. Indeed, an outcome is not necessarily connected to an action, but it needs to be connected to the goal of the action (Gibson, 1979).

Criteria #3
This criteria defines how affordance has range: it is not binary but it possess several gradations. This concept allows to see affordances as dynamic, concept needed in order to properly take into account the nature of digital artefacts, in contrast with the Gibsonian view according to whom affordance should remain constant. According to Evans (2017), this will allow future statistical analysis about affordances' perception.
Affordances' variability is evident in several empirical works, demonstrating how contradictory behaviors of individuals using the same features lead to the achievement of different outcomes.

3.4.2 Definition of Digital Affordance

Starting from the work of Evans (2017) and of Leonardi (2013), the concept of digital affordance is defined in the work of Perpignano (2020) as the set of affordances that arise from the particular nature of digital artefacts, determined by the set of relationships existing between the affordances.

This definition is based on the concept of nested affordances, set of affordances with a spacial, temporal and functional link, including also the concept of sequential affordances.

The presence of nested affordances and the characteristic of duality of a digital artefact lead to the creation of a hierarchy of affordances, and a division in sensory and experiential.

The definition of *Sensory affordances* is identified in the thesis work of Perpignano (2020). It was presented for the first time by Gibson at the end of the 70's, as something related to the sensory perception of the artefact, stimulating the user to undertake an action with it, through a recall to past memory. This type of affordances manifest themselves ex-ante, before the action is undertaken, and arise together with the architecture.

Experiential affordances have been instead defined more recently in the work of Pucillo and Cascini (2014), as related to the perceptions that arise during the usage of the artefact, manifesting ex-post, after the action has been accomplished and eventually able to intervene in future actions.

Perpignano (2020) associated sensory affordances to the product and experiential affordances to the service. However, after the progress made by Tiotto (2022), taking into account that there exists a category of digital artefacts that comprehends both products and services, it is better to associate the affordance categories to the different components of the artefact. In particular, sensory affordances are related to the material component of the artefact, while experiential affordances are related to the immaterial one.

Therefore, when dealing with sensory affordances the following attributes have to be taken into account:

- Physical component of the artefact;
- interface between artefact and user and their interaction.

When dealing with experiential affordances, instead, the attributes to consider are:

- Intangible component of the artefact;
- interface between artefact and user and their interaction;
- the characteristic of experience good;
- the information exchange allowed by a digital artefact.

The concept of digital affordance was further analyzed in the work of Sanna (2022), who defines it as:
"Digital Affordance is a hierarchy of affordances that arises from the flexible nature of the design constraints of the digital artefact, determined by the set of relationships existing between the affordances themselves.
It must be goal-oriented, its perception can be sensory and/or experiential and depends on the information context as well as on the relationships between the affordances themselves".

This definition provides an insight on the main features of digital affordances, mainly the *goal - orientation*, the *dependence on the information context*, the *dependence on flexible design constraints*, the *sensory or experiential perception* and the *hierarchical relationship between affordances* (Colombo, Montagna, Cascini, Palazzolo, 2022).

3.5 Evaluation of affordances

Recalling the work of Pucillo and Cascini (2014), it is possible to resort to the usability concept as a measure to evaluate the affordance of a system.
Nevertheless, study the usability linked to an affordance can be extremely complex, since the concept of affordance is somehow abstract. Given this premises, and referring to the work of (Chenyi Chen, 2015) , it was decided to make an approximation and evaluate the affordance of a system through the evaluation of some "affordance indicators".

Usability can be seen as the quality of use within a given context, general property belonging to any system. The ISO 9241-11 standard defines usability as "The Efficiency, Effectiveness and Satisfaction with which a specific user is able to achieve certain objectives in a given environment".

Therefore, one alternative for the study of the usability of a system, is to analyze the three variables suggested by the ISO standard:

- *Efficiency*: resources, such as time, human effort, costs and material resources, employed when achieving a specific goal (Bevan, 2015).
- *Effectiveness*: measure through which a goal is achieved, defined in terms of accuracy, completeness and appropriateness (Bevan, 2015).
- *Satisfaction*: measure that evaluates the general usefulness perceived by the user when interacting with the system (Bevan, 2015).

Given the subjective and qualitative nature of Satisfaction, of the three variables it is the most complex to analyze. Nevertheless, Satisfaction is an important variable since it offers an indication of the perception that the user has of the usability of the system. In order to have a uniform judgment, this variable is constructed as a compounded variable, typically made up of four qualitative sub-variables that have been converted on a 5-level Likert scale (Likert, 1932).

Using usability as a mean for assessing affordance is an approximate solution to the problem of objective measurement of affordance. A quantitative method allowing to evaluate affordance in an objective manner does not emerge from the literature. However, it is suggested to exploit usability to obtain an affordance evaluation (McGrenere J., 2000).

3.6 Method for the evaluation of Affordances of a Digital Artefact

The problem of the evaluation of affordances enabled by a digital artefact has been analyzed in the work of Perpignano (2020) and is composed by nine steps:

1. *Identification of the actors*: within the digital system, all the actors involved are identified and their profiles are provided, the objectives are highlighted, and the modes of interaction with the artefacts within the system are identified.
2. *Construction of the flowchart*: it includes all the possible paths that the user can undertake in using the digital artefact and the states and actions that he will have to face.

3. *Definition of the architecture*: represented by a block diagram, it shows the relationships between the functional modules and how the artefact works at the level of the functions and information exchanged; through the functional modules it is possible to go back to the functional elements underlying each one. The architecture can be re-elaborated in a hierarchical way to highlight the order relationships between the modules and the elements, which will reflect the hierarchical order established between the nested affordances of the artefact.

4. *Identification of the affordance indicators*: from the functional modules of the system architecture, the functional constituent elements are derived, identified as the key indicators of the affordance; these are grouped into 5 system characteristics, taken from Roskos (2017), which are able to describe the digital system in an exhaustive manner.

5. *Identification of the affordances*: from the functional structure of the system affordances are expressed in the form of relationships (Maier and Fadel 2009; Evans, 2017), and are subsequently organized in order to highlight the possible connections between them, to identify the impact on the digital system.

6. *Construction of the incidence matrix*: an interaction matrix is defined, correlating the affordance indicators on the columns and the enabled affordances on the rows; from this it is possible to determine which indicators enable certain forms of affordance.

7. *Evaluation of the indicators of affordance*: each intersection is evaluated through the use of a Guttman scale, where +1 indicates a positive perception of the indicator, 0 indicates the inability to provide an evaluation and -1 indicates a negative perception.

8. *Affordance evaluation*: derived from the evaluation of the affordance indicators; the digital artefact is evaluated under the point of view of the affordance, based on the answers obtained in the previous point. It is possible to identify which aspects of the system need to be improved and whether there is a prevalence of one of the two types of affordances: *sensory*, linked to the perception of the artefact, or *experiential*, linked to the perception of the service.

9. *Evaluation and considerations of the digital artefact only*: given the results of step 8, the analysis of the affordance indicators is deepened; in particular, the sensory output generated by the artefact (vibrations, sounds, lights, images, etc.) is highlighted, as well as the role played

by the graphic elements of the interface (buttons, icons, colors, position of the text, etc.). These are particularly related to the social conventions which represent an element that facilitate the interpretation of the affordance by the user.

3.7 Modifications of step four: Categories for affordance indicators

Step four of the model is based on the clustering of the affordance indicators as proposed by Roskos (2017).
These are divided into 6 characteristics of the digital system and are described in Table 3.1.

Category	Definition
Functionality	Useful for educational purpose; Graphical design reflects effective layout and visual hierarchy; Allows for integrative functioning
Communication	Supports various communication types (user-user, user-device)
Accessibility	Describes user status; Meets user specific needs; Supports mobility; Supports different languages
Administration	Quick and easy to set up; Re-configurable; Customizable; Easy to upgrade; Accurate consistent operation
Instrument	Efficient performance; Provides different functionality layers
Content	Useful; Suitable to meet educational objectives; Flexible, simple and self-explanatory; Mobile

Table 3.1: Six categories used to describe digital systems by Roskos (2017).

As already stated in (Sanna, 2022) and in (Tiotto, 2022), it is useful to redefine the categories of affordance indicators.

The following modifications have been made by Tiotto (2022) and will be then used for the rest of the analysis in this thesis work:

- The two categories *Functionality* and *Instrument* are merged into a single category, since their similitude risked to confuse respondents, distorting the results obtained.

  The new category is then divided into two categories, *Basic functionality*, including indicators related to the basic functions that an artefact must necessarily have, and *Additional Functionality*, including indicators that improve the *user experience*. The definitions are the following:

  Basic Functionality: indicators useful for achieving the goal and allowing integrative functioning; what concerns the graphic design, the layout and the visual hierarchy.

  Additional Functionality: indicators related to the improvement of the user experience and which make performance more efficient and stable.

- Also the two categories *Accessibility* and *Administration* are merged into a single one, because of the number of common characteristics. In particular, indicators of the Administration category seemed to belong to the Accessibility one. For this reason, only this category has been kept, with a more complete definition:

  Accessibility: indicators useful to understand how easy it is for the user to interface with the artefact (e.g. multilingual, free of charge, methods of use, ease and speed of updating and configuration, consistency in operation, etc.).

- The two categories *Communication* and *Content* have been kept, but their definitions have been updated, in order to have a clearer meaning:

  Communication: indicators useful for communication between different actors, between user and artefact and between user-artefact and environment.

  Content: indicators useful for the maintenance and organization of data.

  A slightly modification has been made to the definition of this category when submitting the questionnaire, in order to highlight the importance of data in this category. This was done since for respondents the definition was not so clear and straightforward, as emerged by the first interviews.

  Content: indicators related to data and their maintenance and organization.

As in (Sanna, 2022) and (Tiotto, 2022), also the Shao dimensions (2020) have been taken into account. Their definition is the following:

- *Interactivity*: It concerns users' perception of communication and interaction with others.
- *Navigation*: It concerns the ease of use and intuitiveness in the use of the digital artefact.
- *Information*: It concerns the creation, storage, transformation and exploitation of information in the use of digital artefacts.

Table 3.2 summarizes the new definitions of the categories and dimensions that will be then used in the following analysis.

Category/ Dimension	**Definition**
Basic Functionality	Indicators useful for achieving the goal and allowing integrative functioning; what concerns the graphic design, the layout and the visual hierarchy
Additional Functionality	Indicators related to the improvement of the user experience and which make performance more efficient and stable
Accessibility	Indicators useful to understand how easy it is for the user to interface with the artefact (e.g. multilingual, free of charge, methods of use, ease and speed of updating and configuration, consistency in operation, etc.).
Communication	Indicators useful for communication between different actors, between user and artefact and between user-artefact and environment.
Content	indicators related to data and their maintenance and organization.
Interactivity	It concerns users' perception of communication and interaction with others.
Navigation	It concerns the ease of use and intuitiveness in the use of the digital artefact.
Information	It concerns the creation, storage, transformation and exploitation of information in the use of digital artefacts.

Table 3.2: Updated definitions of categories and dimensions used to describe the digital system.

3.8 Review of the relationship between Categories and Affordances

Step 4 of the model aims at associating categories and dimensions to sensory or experiential affordances. A review of the results of precedent thesis works has been done, as shown in Tables 3.3 and 3.4.

There have been highlighted in *light blue* and with a *question mark* the cases in which it was not possible to uniquely associate a category or dimension to the sensory or experiential component. In *green*, instead, are highlighted the cases in which the association was not in line with the theoretical model previously defined.

CATEGORY/ DIMENSION	THEORETICAL MODEL	CASE STUDY	Food delivery		Bim - Based system
		METHOD	Questionnaire to users of the app	Questionnaire to users of the app - indicators update	Interview with key figures
Functionality	Sensory		Sensory	Sensory	?
Instrument	Experiential		Experiential	Experiential	Sensory
Communication	Sensory		Sensory	Sensory	?
Accessibility	Experiential		?	Experiential	Sensory
Administration	Experiential		?	-	?
Contents	Experiential		-	-	Experiential
Interactivity	Sensory		-	Sensory	?
Navigation	Sensory		-	Sensory	Sensory
Information	Experiential		-	Experiential	Experiential

Table 3.3: Analysis of the association of categories and dimensions to sensory and experiential component in previous thesis works.

NEW CATEGORY/ DIMENSION	CASE STUDY	Food delivery
	METHOD	Update of Roskos categories division
Basic functionality		Sensory
Additional functionality		Experiential
Communication		Sensory
Accessibility		?
Contents		Sensory
Interactivity		Sensory
Navigation		?
Information		Experiential

Table 3.4: Analysis of the association of categories and dimensions to sensory and experiential component in previous thesis works after the update of Roskos categories.

Previous works focused in particular on the case study of Food Delivery, then analyzed in (Colombo, Montagna, Cascini, Palazzolo, 2022).
In the first analysis (Perpignano, 2020) only Roskos categories were considered, without taking into account the category "Content". It emerged that categories "Accessibility" and "Administration" could not have a unique allocation to sensory or experiential affordances.

For the second analysis (Franceschi, 2021) also Shao dimensions were taken into account, and a proper review of the affordance indicators was performed. Even in this work the category "Content" was not considered, as well as the category "Administration". For the remaining categories and dimensions it emerged a unique association to one cluster of affordance. After the review of the the Roskos categories made in (Tiotto, 2022), the case study has been analyzed a third time (Table 3.4).

The model has been also applied to a case study related to Bim-based systems (Sanna, 2022). In this case the allocation was more ambiguous, since for most of the categories and dimensions the association was not unique or it was not in line with the theoretical model ex-ante defined.

Given the lack of a clear pattern in their association to sensory or experiential affordances, "Accessibility" and "Content" categories must be properly taken into account in the following analysis, as well as "Navigation" dimension. Moreover, even if "Interactivity" has always resulted sensory, it seems to be anomalous, given that it implies an interaction with others.

4 Case study

In this thesis work the model for the identification and evaluation of affordances of a digital artefact has been applied to a case study that aims to compare a digital product and a digital service.

Given the classification of artefacts provided in Figure 4.1, it has been decided to compare two digital artefacts coming from the the music industry: a music CD, representing a digital product, and a music Streaming Service, such as Spotify and Amazon Music, representing a digital service.

The aim is to analyze analogies and differences in the study of affordances related to different digital artefacts and how users' behavior changes when interacting with them.

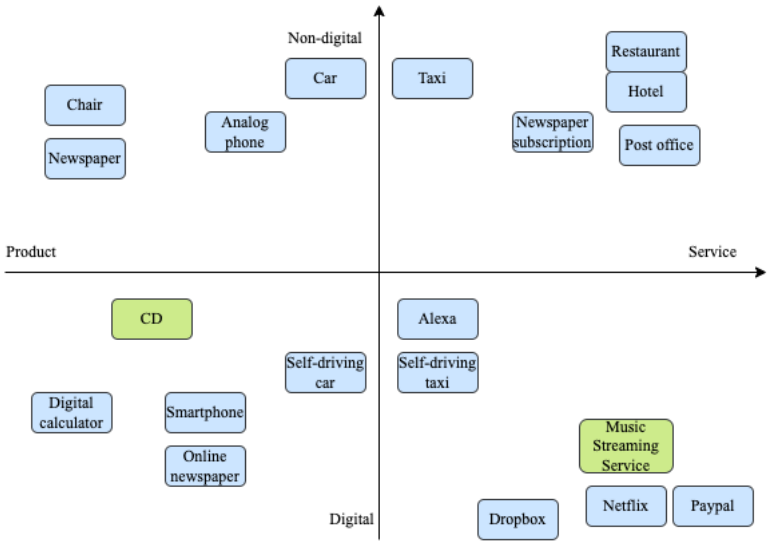


Figure 4.1: Examples of artefacts' classification.

A compact disc is a portable storage medium that can be used to record, store and play back audio, video and other digital forms [31]. A streaming service is an audio streaming and media services provider, offering digital copyright restricted recorded musics and podcasts [32].
Internet advancements and technological discoveries led to a shift from the usage of physical mediums to the use of digital platforms, allowing the access to music from digital devices. Despite the lower quality level of the streaming, lower cost and convenience started to attract customers from the beginning of its diffusion [28].

4.1 Step 1: Actors identification

In the first Step of the model the main actors involved have been identified.

Music CD

- *Users*: they look for a CD that can be related to a particular album or to a particular artist they like. Their objective is to find the exact album or collection of songs they are searching for.
- *Artists/ Producers*: those who produce the contents of CDs. The objective is the maximization of the number of CDs sold, for both reasons related to revenues and to the fact of being known.
- *Sellers*: those who sell CDs. The objective is the maximization of the number of CDs sold, to maximize the profit.

Music Streaming Service

- *Users*: the objective is to find songs, albums, artists or even podcasts they like, with the possibility of personalizing their experience, creating their own playlists and receiving customized suggestions, according to their own taste.
- *Artists/ Producers*: those who produce the contents. The objective is the maximization of the number of stream, for both reasons related to revenues and to the fact of being known.

4.2 Step 2: Construction of the flowchart

In the second Step, two flowcharts have been made, by using BMPN.

Music CD
For the music CD, the flowchart represents the interaction between the user and the CD, starting from the decision to search a new CD until the analysis of the different activities it can be used for.

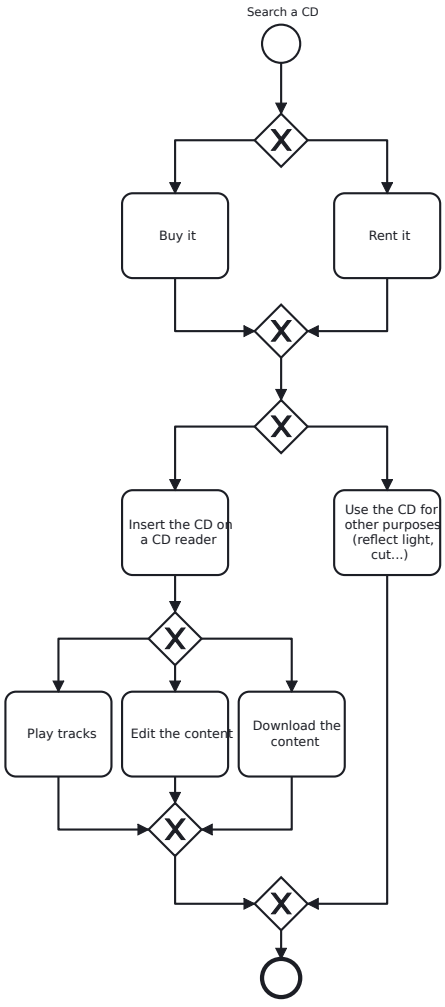


Figure 4.2: Flowchart showing the interaction between the user and the music CD.

As shown in Figure 4.2, after having purchased or rented it, a music CD can be used to listen audio tracks or to look at the additional contents it may have, such as videos or images. It is also possible to modify or download the different contents. CDs can also be used for different and unusual purposes, as to reflect light or to cut something, but also as coaster or as scarecrow.

Music Streaming Service

For music Streaming Services the flowchart shows the different pathways the user can undertake once she has decided to open the application.

As shown in Figure 4.3, music Streaming Services are characterized by three main pages: home page, library page and search page. The home page contains recommended songs and playlists, playlists made ad-hoc for the user and the most recently played songs; it also allows to go to system settings. From the search page, instead, it is possible to search for songs, albums, artists and podcasts. Library page contains liked songs and personal playlists and allows to create new playlists. When playing a song it is possible to add it to a playlist, add it to the queue, go to the corresponding album/artist or share it with other users.

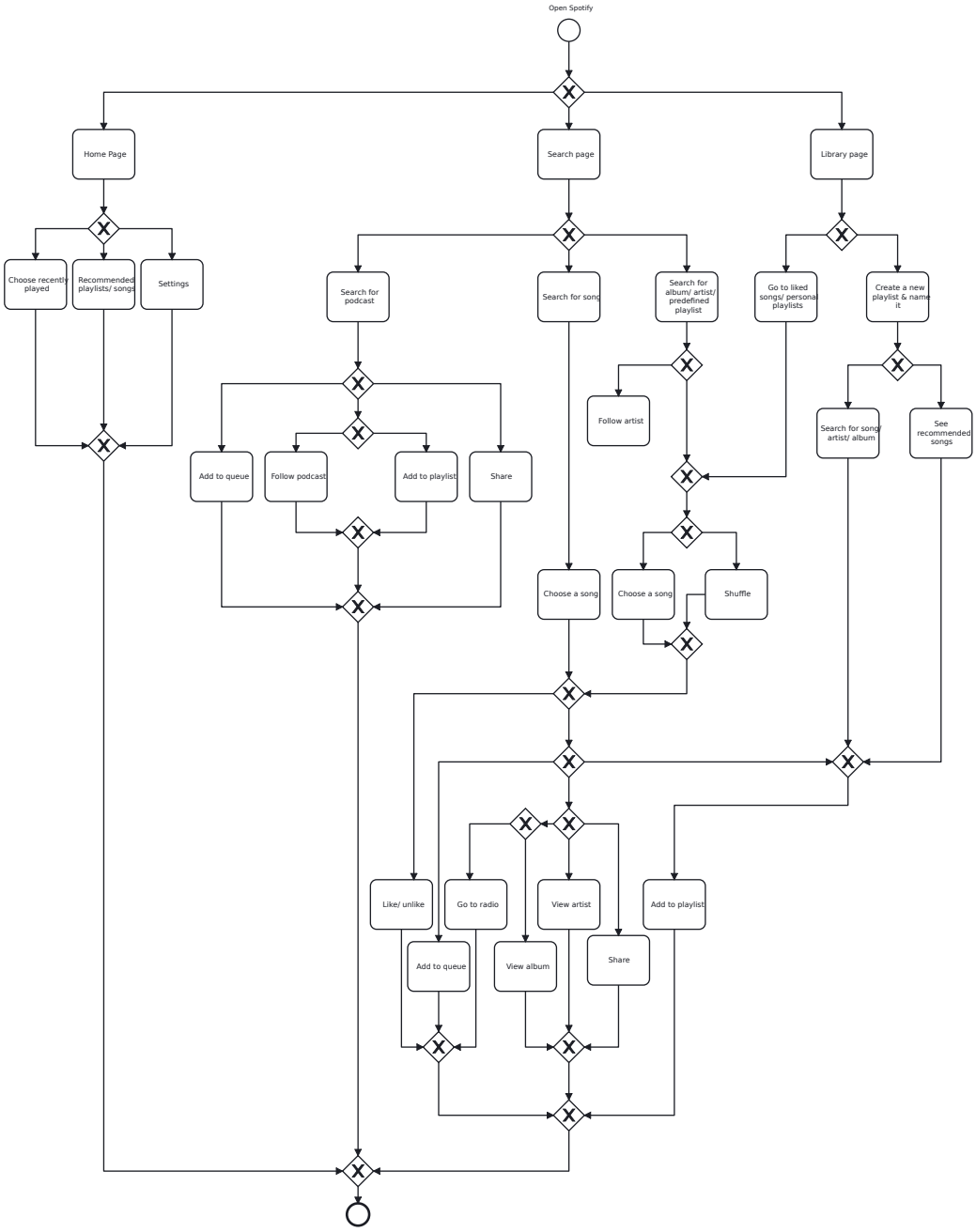


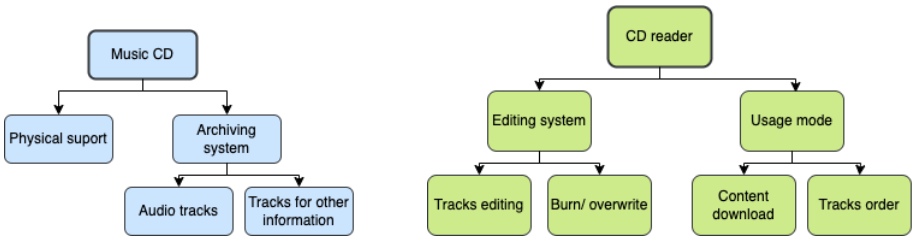
Figure 4.3: Flowchart showing the interaction between the user and the music Streaming Service.

4.3 Step 3: Definition of the architecture

In the third Step, the architecture of the two artefacts has been defined, by using a product tree.

Music CD

For music CDs, two different architectures have been defined (Figure 4.4): one for the music CD itself and one for the CD reader that allows its usage.



(a) Architecture of the music CD.

(b) Architecture of the CD reader.

Figure 4.4: Music CD and CD reader architecture.

Music Streaming Service

In case of the Streaming Service, the graph in Figure 4.5 has been made. It shows the main components of the system (in light blue) and how these interrelate with the activities the user can undertake (in green).

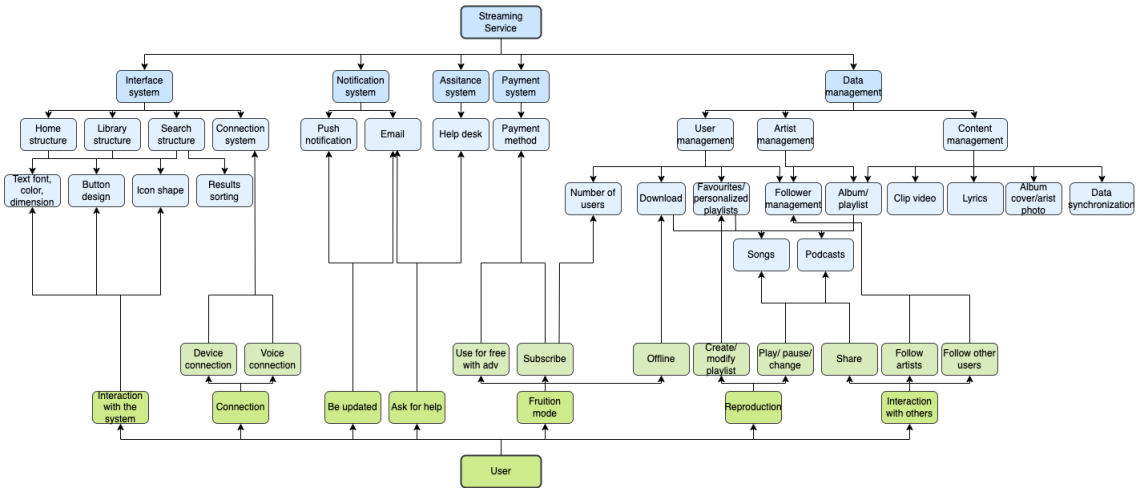


Figure 4.5: Interaction between the Streaming Service components and the actions performed by the user.

4.4 Step 4: Identification of affordance indicators

In Step 4 indicators for both music CDs and Streaming Services have been identified. The identification has been carried out by thinking about the main usage of the artefact, taking into account also the flowchart and the system architecture defined in Step 2 and 3 of the model, but also by thinking to unusual uses, in particular for CDs, such as the possibility to use it to reflect light or to cut something.

Also indicators identified in previous works (Sanna, 2022) and (Tiotto, 2022) have been used as a basis for indicators identification, considering both the ones that could be used for the case study exactly as they were, and those that could be used after a slight modification needed to fit the specific case.

The lists of the affordance indicators with their identification number, for both music CDs and Streaming Services, are provided in Tables 4.1 and 4.2 respectively.

Music CD			
Shape	I1	Tracks order	I9
Color	I2	Content download	I10
Material	I3	Rental	I11
Surface	I4	Purchase	I12
Thickness	I5	Audio editing	I13
Cover image	I6	Video editing	I14
Audio tracks	I7	Tracks name modification	I15
Additional content	I8	Content editing	I16

Table 4.1: List of affordance indicators for music CDs.

Streaming Service			
Text font	I1	Device connection	I19
Text color	I2	Results sorting	I20
Text dimension	I3	Search function	I21
Sharing system	I4	Voice connection	I22
Notification system	I5	Download(song/album/podcast)	I23
Email	I6	Number of users	I24
Favourites	I7	User profile	I25
Personalized playlists	I8	Lyrics	I26
System settings	I9	Library structure	I27
Language settings	I10	Collaborative playlist	I28
System for playlist creation	I11	Help desk	I29
System for songs removal from playlist	I12	Clip video	I30
Follow artists	I13	Album cover/ Artist photo	I31
Button design	I14	System for pausing/changing songs	I32
Icon shape	I15	Follow other users	I33
For free with advertisement	I16	Data synchronization	I34
Subscription	I17	Payment method	I35
Home structure	I18		

Table 4.2: List of affordance indicators for Streaming Services.

4.4.1 Case study analysis

The case study has been analyzed through a series of interviews, conducted with the users of the two artefacts. In particular, 30 people have been interviewed, by using different devices (e.g. Skype, Microsoft Teams, Google Meets), according to the specific needs of respondents.

4.4.2 Structure of the interview

During the interview, it was asked to the respondent to compile an Excel file, composed by five sections:

- *Section 1*: Personal data and questions related to the usage of the two artefacts.
- *Section 2*: Definition of the belonging of the indicator to the sensory or experiential component.
- *Section 3*: Definition of the most appropriate category for each indicator.

- *Section 4*: Definition of the most appropriate dimension for each indicator.
- *Section 5*: Definition of the belonging of each category/dimension to the sensory or experiential component.

The sections were preceded by a sheet containing all the relevant information: the definition of indicators, of sensory and experiential component and of categories and dimensions. It also contained the description of the different sections and a guide to understand how to compile them.

A brief explanation of the different sections is provided below:

- *Section 1*: contained general questions regarding age, gender, occupation and questions related to the usage of the two artefacts, such as the frequency of usage.
- *Section 2*: after the description of the sensory and experiential components of the artefact, the sheet presented a column with the list of indicators, first for music CDs and then for Streaming Services and on its right two additional columns, one for the sensory component and one for the experiential one.
  A short description of each indicator has been provided as well.
- *Section 3*: after the description of the categories (Basic Functionality, Additional Functionality, Accessibility, Communication, Content), the sheet presented a column with the indicators, first for music CDs and then for Streaming Services, and on its right five columns, one for each category.
  A short description of each indicator has been provided as well.
- *Section 4*: after the description of the dimensions (Interactivity, Navigation, Information), the sheet presented a column with the indicators, first for music CDs and then for Streaming Services, and on its right three columns, one for each dimension.
  A short description of each indicator has been provided as well.
- *Section 5*: the last section presented a column with the name of each category/dimension analyzed in Section 2 and 3, and on its right two additional columns, one for the sensory component and one for the experiential one.
  In order to avoid having to go back to previous sections, the definition of categories and dimensions has been reported in Section 5 as well.

A synthesis of the questionnaire structure is presented in Figure 4.6.

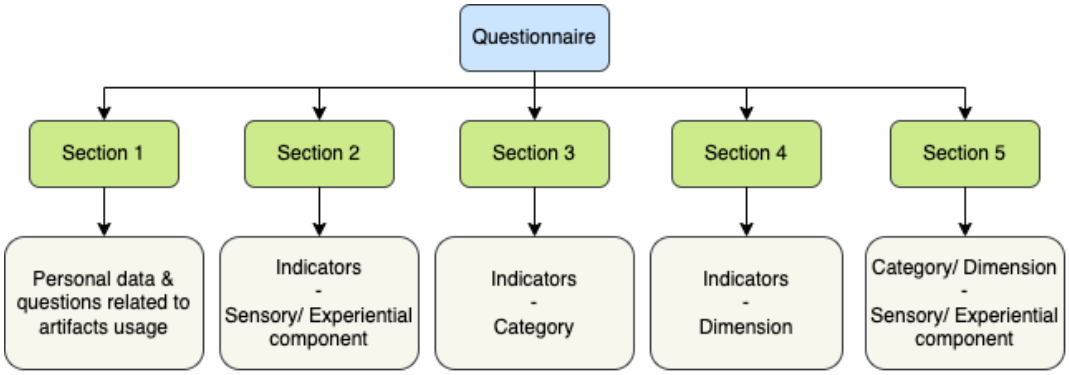


Figure 4.6: Questionnaire structure.

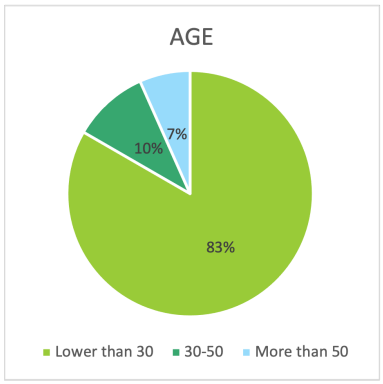
4.4.3 Results Analysis

Each Section of the questionnaire has been used to make different analysis. The summary of the analysis is shown below:

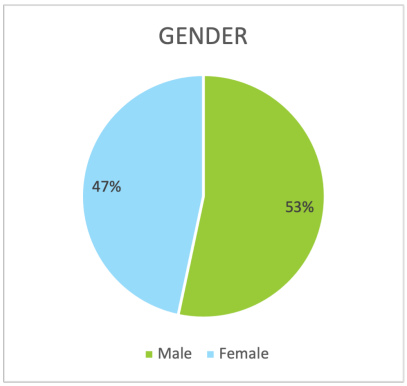
- *Section 1*, related to personal data and to the usage of the two artefacts, was used to make a profiling of respondents.
- In *Section 2* it was asked to associate the indicators to the sensory or experiential component. The answers given to this Section were used after the analysis of Section 3 and 4 and after having update the allocation of some indicators into the different categories/dimensions. In particular, a t-test was performed, in order to validate the statistically significant difference in attributing a category/dimension to the sensory or experiential component of the artefact.
- In *Section 3* it was asked to associate the indicators to the modified categories of Roskos and it was analyzed if the answers were in line with the theoretical allocation, defined ex-ante.
- In *Section 4* it was asked to associate the indicators to the dimensions of Shao and it was analyzed if the answers were in line with the theoretical allocation, defined ex-ante.
- In *Section 5* it was asked to associate categories and dimensions to the sensory or experiential component, in order to verify the consistency of the answers. In particular, the answers were compared with the allocation in the theoretical model and with the results emerged from the t-test, for both music CD and Streaming Service.

Section 1 - Personal data and artefacts usage

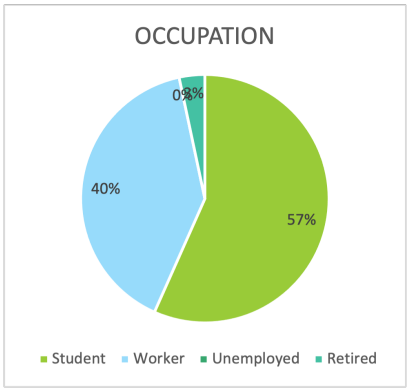
In Section 1, questions related to personal data and to the usage of the two artefacts were asked.



(a) Figure showing respondents age.



(b) Figure showing respondents gender.



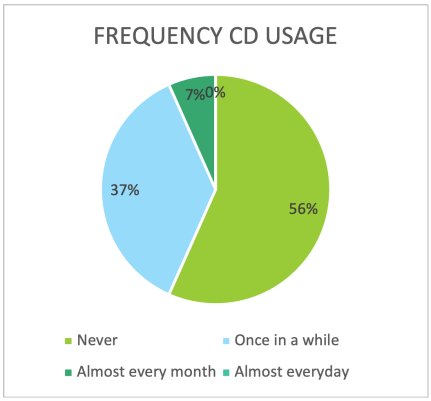
(c) Figure showing respondents occupation.

Figure 4.7: Respondents personal data.

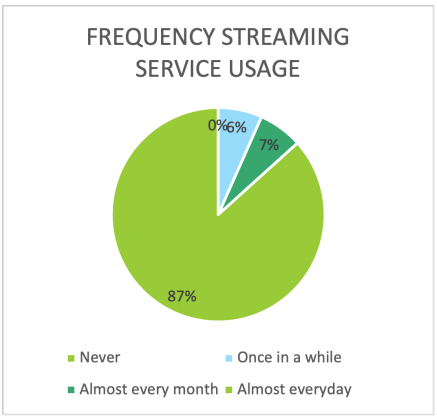
From the analysis of personal data, reported in Figure 4.7, it emerged that 53% of respondents are male and 47% female; 83% of them is under the age of 30, percentage in line with statistics [30].
Regarding the occupation, the majority are students (57%), followed by workers (40%).

Form the analysis of the questions related to the usage of the two artefacts, the first evidence is that every respondent has used at least once

both CDs and Streaming Services to listen to music.
The difference between the two artefacts lies in the frequency of the usage: if the 57% of respondents never uses CDs nowadays, there is no respondent that does not use Streaming Services at all. This evidence highlights the transition from the use of physical products to the use of digital services, enabled by digitization and technological advancements.



(a) Figure showing the frequency of respondents usage of CDs.



(b) Figure showing the frequency of respondents usage of Streaming Services.

Figure 4.8: Respondents frequencies of usage.

Furthermore, in case of CDs, the 37% of respondents uses them only once in a while and the remaining percentage (7%) uses them almost every month, as shown in Figure 4.8. For Streaming Services, instead, 87% of respondents uses them almost everyday, while the remaining 14% is split equally between those who use it almost every month and those who use it only rarely.

Regarding the type of Streaming Service, only one respondent does not use Spotify, underlining its position as market leader, with a market share of 31% [2]. The 20% uses also Amazon Music, while Apple Music is used by the 13% of respondents. Finally, only 7% of them uses different types of Streaming Services, mainly YouTube (Figure 4.9).

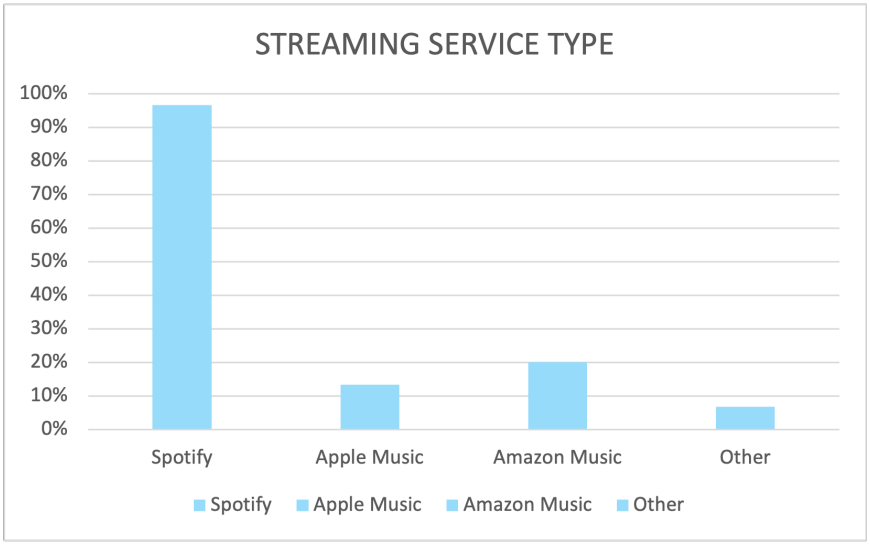


Figure 4.9: Figure showing the main Streaming Services used by respondents.

Section 2: Indicators allocation to Sensory and Experiential component

This Section will be then used for the t-test analysis, but a preliminary analysis has been done to highlight indicators that do not have a clear allocation between the two components. Respondents answers for music CD and Streaming Service, in percentage, are reported in Tables 4.3 and 4.4 respectively.

For *Music CDs* only two indicators do not have a clear allocation between sensory and experiential component: *Additional content*, with 47% for sensory and 53% for experiential and *Rental*, with 57% and 43%, even if these percentages are close to the one of the associated indicator *Purchase*, which has 60% versus 40%.

Music CD		
INDICATORS	SENSORY	EXPERIENTIAL
Shape	97%	3%
Color	100%	0%
Content download	20%	80%
Tracks order	33%	67%
Content editing	17%	83%
Material	100%	0%
Tracks audio	27%	73%
Audio editing	3%	97%
Video editing	3%	97%
Additional content	47%	53%
Surface	100%	0%
Thickness	100%	0%
Purchase	60%	40%
Rental	57%	43%
Cover image	97%	3%
Tracks name modification	13%	87%

Table 4.3: Music CD affordance indicators allocation to sensory and experiential component.

In case of *Streaming Services*, instead, two indicators (*For free with advertisement* and *Search function*) are allocated by half of respondents to the sensory component and by the other half to the experiential one. *For free with advertisement* should have an allocation similar to the one of *Subscription*, given the relationship between the two indicators; nevertheless, there seems to be a much clearer distinction in case of *Subscription*. Also *Album cover/ Artist photo* indicator does not have a clear allocation, given the 53% for the sensory component and 47% for the experiential one. A slightly clearer distinction is given to *Voice connection*, *Number of users*, *Clip video* with 43% versus 57%.

Streaming Service		
INDICATORS	SENSORY	EXPERIENTIAL
Text font	90%	10%
Text color	93%	7%
Text dimension	93%	7%
Sharing system	17%	83%
Notification system	17%	83%
Email	10%	90%
Favourites	10%	90%
Personalized playlists	7%	93%
System settings	27%	73%
Language settings	37%	63%
System for playlist creation	27%	73%
System for songs removal from playlist	23%	77%
Follow artists	17%	83%
Button design	80%	20%
Icon shape	80%	20%
For free with advertisement	50%	50%
Subscription	37%	63%
Home structure	60%	40%
Device connection	30%	70%
Results sorting	13%	87%
Search function	50%	50%
Voice connection	43%	57%
Download (song/album/podcast)	30%	70%
Number of users	43%	57%
User profile	33%	67%
Lyrics	30%	70%
Library structure	30%	70%
Collaborative playlist	10%	90%
Help desk	27%	73%
Clip video	43%	57%
Album cover/ Artist photo	53%	47%
System for pausing/ changing song	37%	63%
Follow other users	10%	90%
Data synchronization	20%	80%
Payment method	47%	53%

Table 4.4: Streaming Service affordance indicators allocation to sensory and experiential component.

Section 3 and 4: Indicators allocation to categories and dimensions

In Section 3 it was asked to allocate each indicator to the updated Roskos categories, while in Section 4 it was asked to do the same for Shao dimensions.
It was then analyzed if the association was in line with the theoretical model defined ex-ante. In particular, the analysis of the answers given for each indicator takes into account the category/dimension chosen from the majority of respondents, or the one with highest percentage.
Indicators whose allocation differ between the theoretical model and the results of the analysis have been highlighted in *light blue* in Tables 4.5, 4.6 and 4.7.

Music CD - updated Roskos categories

- **Basic functionality**: 75% of the indicators were correctly allocated: *Shape*, *Color*, *Material*, *Surface*, *Thickness*, *Cover image*.
  Content download has been allocated by the majority of respondents to "Additional Functionality" category. It seems reasonable since it can be considered as an additional feature of CDs, whose main purpose is to let users listen to music or look at its contents.
- **Additional functionality**: Of the two indicators theoretically allocated to "Additional functionality", only one (*Tracks name modification*) is actually allocated by respondents to this category.
  60% of respondents allocates *Tracks order* to "Content" category, and this seems reasonable since the order is related to the main content of CDs.
  Content download and *Content editing* are inserted here instead of the category “Basic Functionality”.
  Audio editing and *Video editing* were theoretically associated to “Communication” category because of the possibility of communicating something to others. Nevertheless, only 13% of respondents allocated them to that category. Given that 77% of respondents associated them to “Additional Functionality”, it has been decided to add them here, since they can be considered as something related to the improvement of the user experience.
- **Accessibility**: 100% of the indicators theoretically allocated to this category (*Rental* and *Purchase*) were correctly allocated.

- **Communication**:: after the shift of *Audio editing* and *Video editing*, this category is not taken into account anymore for the Music CD. This is in line with the theory because it seems reasonable that, in case of digital products, communication category, implying an interaction with others, is not present.
- **Content**: It is not so clear the allocation of the two indicators of this category (*Tracks audio* and *Additional Content*), since almost half of the respondents correctly allocated them, but the others allocated them to "Basic Functionality" and "Additional Functionality" categories. Anyway, their collocation has not been changed.
  Moreover, the indicator *Tracks order* has been added in this category.

Table 4.5 shows the theoretical and experimental allocation of the indicators for each category.

Music CD									
BASIC FUNCTIONALITY		ADDITIONAL FUNCTIONALITY		ACCESSIBILITY		COMMUNICATION		CONTENT	
Theoretical	Experimental	Theoretical	Experimental	Theoretical	Experimental	Theoretical	Experimental	Theoretical	Experimental
Shape	Shape	Tracks name modification	Tracks name modification	Rental	Rental	Audio editing		Tracks audio	Tracks audio
Color	Color	Content download	Content download	Purchase	Purchase	Video editing		Additional content	Additional content
Material	Material	Tracks order	Content editing						Tracks order
Surface	Surface		Audio editing						
Thickness	Thickness		Video editing						
Cover image	Cover image								
Content editing									

Table 4.5: Indicators allocation to updated Roskos categories - Comparison between the theoretical model and the interviews results for Music CD.

Music CD - Shao dimensions

- **Interactivity**: *Content editing*, *Audio editing* and *Video editing* were theoretically considered in this dimension, but most of respondents allocated them to "Information", which seems reasonable since they are all indicators related to the management and manipulation of the information contained in the artefact. For this reason, they are shifted into "Information" dimension.
  Moreover, *Rental* and *Purchase*, theoretically allocated to "Navigation" dimension, were allocated here. This makes sense considering that, differently from the case of Streaming Services, most of the time the rental or purchase of a disc implies the interaction with

others (in particular the seller). For this reason, it has been decided to shift them into this dimension.

- **Navigation**: Excluding indicators Rental and Purchase, all the other indicators theoretically associated to this dimension were correctly allocated: *Shape*, *Color*, *Material*, *Surface*, *Thickness*, *Tracks order*.
- **Information**: 100% of the indicators theoretically associated to this category (*Tracks audio*, *Additional Content*, *Cover image*, *Tracks Name modification*, *Content download*) were correctly allocated. Moreover, as previously stated, indicators *Content editing*, *Audio editing* and *Video editing* were inserted here.

Table 4.6 shows the theoretical and experimental allocation of the indicators for each dimension.

Music CD					
INTERACTIVITY		NAVIGATION		INFORMATION	
Theoretical	Experimental	Theoretical	Experimental	Theoretical	Experimental
Content editing	Purchase	Shape	Shape	Tracks audio	Tracks audio
Audio editing	Rental	Color	Color	Additional content	Additional content
Video editing		Material	Material	Cover image	Cover image
		Surface	Surface	Tracks name modification	Tracks name modification
		Thickness	Thickness	Content download	Content download
		Tracks order	Tracks order		Content editing
		Rental			Audio editing
		Purchase			Video editing

Table 4.6: Indicators allocation to Shao dimensions - Comparison between the theoretical model and the interviews results for Music CD.

Music Streaming Service - updated Roskos categories

- **Basic functionality**: 100% of the indicators were correctly allocated: *Text font*, *Text color*, *Text dimension*, *Search function*, *Home structure*, *System for changing/ pausing song*.
  Button design and *Icon shape* indicators were theoretically associated to "Accessibility", but they are both related also to the basic layout of the service; therefore, given respondents answers, it has been decided to shift them into this category.
- **Additional functionality**: 88% of the indicators were correctly allocated: *Results sorting*, *Library Structure*, *Lyrics*, *Follow artists*,

Download (song/album/podcast), *System for playlist creation*, *System for songs removal from playlist.*
Data synchronization indicator, theoretically collocated in this category, was allocated correctly only by 23% of respondents, while 33% of them allocated it to "Content". Since this latter category is related to data, their maintenance and organization, it seems reasonable to shift the allocation of this indicator.
Moreover, 73% of people allocated *Clip video* indicator to this category instead of the theoretical one, "Content". Since it can for sure be considered as an additional feature, improving the user experience, Clip video is shifted in "Additional Functionality". The same for *Album cover/Artist photo*, even if in that case the distinction between Basic/Additional functionality is less clear.

- **Accessibility**: Excluding *Button design* and *Icon shape*, the allocation of all the other indicators was in line with the theoretical model: *Language settings*, *Payment method*, *System settings*, *Number of users*, *Subscription*, *For free with advertisement*, *User profile.*
- **Communication**: the allocation of all the indicators was in line with the theoretical model: *Email*, *Help desk*, *Sharing system*, *Notification system*, *Device connection*, *Voice connection*, *Follow other users*, *Collaborative playlist.*
- **Content**: Both *Favourites* and *Personalized Playlists* were correctly allocated to this category.
  Clip video and *Album cover/Artist photo* were moved into "Additional Functionality".
  Finally, *Data synchronization* was moved from "Additional Functionality" to "Content" category.

Table 4.7 shows the theoretical and experimental allocation of the indicators to each category.

Streaming Service					
BASIC FUNCTIONALITY		ADDITIONAL FUNCTIONALITY		ACCESSIBILITY	
Theoretical	Experimental	Theoretical	Experimental	Theoretical	Experimental
Text font	Text font	Results sorting	Results sorting	Language settings	Language settings
Text color	Text color	Library structure	Library structure	Payment method	Payment method
Text dimension	Text dimension	Lyrics	Lyrics	System settings	System settings
Search function	Search function	System for songs removal from playlist	System for songs removal from playlist	Number of users	Number of users
Home structure	Home structure	Downolad (song/album/podcast)	Downolad (song/album/podcast)	Subscription	Subscription
System for changing/ pausing song	System for changing/ pausing song	System for playlist creation	System for playlist creation	For free with advertisement	For free with advertisement
	Button design	Follow artists	Follow artists	User profile	User profile
	Icon shape	Data synchronization	Clip video	Button design	
			Album cover/ Artist photo	Icon shape	

Streaming Service			
COMMUNICATION		CONTENT	
Theoretical	Experimental	Theoretical	Experimental
Email	Email	Favourites	Favourites
Help desk	Help desk	Personalized playlists	Personalized playlists
Sharing system	Sharing system	Clip video	Data synchronization
Notification system	Notification system	Album cover/ Artist photo	
Device connection	Device connection		
Voice connection	Voice connection		
Follow other users	Follow other users		
Collaborative playlist	Collaborative playlist		

Table 4.7: Indicators allocation to updated Roskos categories - Comparison between the theoretical model and the interviews results for Streaming Service.

Music Streaming Service - Shao dimensions

- **Interactivity**: 100% of the indicators were correctly allocated. The percentage of respondents that allocated *Help Desk* indicator to this dimension (43%) is the same that allocated it to "Navigation"; anyway, it has been decided not to shift its collocation.
- **Navigation**: the allocation of all indicators has been in line with the theoretical model.
- **Information**: the allocation of all indicators has been in line with the theoretical model.

Table 4.8 shows the theoretical and experimental allocation of the indicators to each dimension.

Streaming Service					
INTERACTIVITY		NAVIGATION		INFORMATION	
Theoretical	Experimental	Theoretical	Experimental	Theoretical	Experimental
Email	Email	Text font	Text font	Favourites	Favourites
Notification system	Notification system	Text color	Text color	Personalized playlists	Personalized playlists
Sharing system	Sharing system	Text dimension	Text dimension	User profile	User profile
Help desk	Help desk	Language settings	Language settings	Album cover/ Artist photo	Album cover/ Artist photo
Device connection	Device connection	Payment method	Payment method	Clip video	Clip video
Voice connection	Voice connection	System for playlist creation	System for playlist creation	Lyrics	Lyrics
Follow other users	Follow other users	System for songs removal from playlist	System for songs removal from playlist	Downolad (song/album/podcast)	Downolad (song/album/podcast)
Collaborative playlist	Collaborative playlist	Results sorting	Results sorting	Data synchronization	Data synchronization
Number of users	Number of users	Search function	Search function		
Follow artists	Follow artists	System for changing/pausing song	System for changing/pausing song		
		Button design	Button design		
		Icon shape	Icon shape		
		Home structure	Home structure		
		Library structure	Library structure		
		For free with advertisement	For free with advertisement		
		Subscription	Subscription		
		System settings	System settings		

Table 4.8: Indicators allocation to Shao dimensions - Comparison between the theoretical model and the interviews results for Streaming Service.

T-test analysis

After the analysis of the indicators allocation to categories/dimensions and the comparison with the theoretical model, a t-test on the single categories and dimensions has been performed.

The null hypothesis (H0) is the following:
H0: There is no statistically significant difference in attributing a category/dimension to the experiential or sensory component, with a 95% confidence interval.

Music CD

In case of the updated categories of Roskos, for music CD, all the categories (excluded "Communication" which, as already stated, is not taken into account for CDs), pass the t-test, meaning that a statistically significant difference can be identified between sensory and experiential component. Table 4.9 reports the results of the t-test for each category, as well as the association to sensory or experiential affordances.

In particular:

- *Basic Functionality*: is correlated to the *Sensory* component;
- *Additional Functionality*: is correlated to the *Experiential* component;

– *Accessibility*: is correlated to the *Sensory* component;
– *Content*: is correlated to the *Experiential* component.

	BASIC FUNCTIONALITY		ADDITIONAL FUNCTIONALITY		ACCESSIBILITY		CONTENT	
	Sensory	Experiential	Sensory	Experiential	Sensory	Experiential	Sensory	Experiential
Mean	29,667	0,333	3,400	26,600	17,500	12,500	10,667	19,333
Standard Dev.	0,516	0,516	2,302	2,302	0,707	0,707	3,055	3,055
Degrees of freedom	10		8		2		4	
t	9,839E+01		15,934		7,071		3,474	
p -value	2,882E-16		2,411E-07		0,019		0,025	
	Ho refused		**Ho refused**		**Ho refused**		**Ho refused**	
	Sensory		**Experiential**		**Sensory**		**Experiential**	

Table 4.9: t-test results for music CD for Roskos updated model.

Even for the Shao dimensions, the null hypothesis is always refused (Table 4.10), meaning that there is a statistically significant difference in allocating the dimensions to the sensory or experiential component.

In particular:

– *Interactivity*: is correlated to the *Sensory* component;
– *Navigation*: is correlated to the *Sensory* component;
– *Information*: is correlated to the *Experiential* component.

	INTERACTIVITY		NAVIGATION		INFORMATION	
	Sensory	Experiential	Sensory	Experiential	Sensory	Experiential
Mean	17,500	12,500	26,500	3,500	5,571	24,429
Standard Dev.	0,707	0,707	8,093	8,093	4,504	4,504
Degrees of freedom	2		10		12	
t	7,071		4,922		7,833	
p -value	0,019		0,001		4,665E-06	
	Ho refused		**Ho refused**		**Ho refused**	
	Sensory		**Sensory**		**Experiential**	

Table 4.10: t-test results for music CD for Shao model.

Music Streaming Service

In case of Streaming Services all the Roskos updated categories have been taken into account. Even in this case, the null hypothesis is refused for each category (Table 4.11).

In particular:

- *Basic Functionality*: is correlated to the *Sensory* component;
- *Additional Functionality*: is correlated to the *Experiential* component;
- *Accessibility*: is correlated to the *Experiential* component;
- *Communication*: is correlated to the *Experiential* component;
- *Content*: is correlated to the *Experiential* component.

	BASIC FUNCTIONALITY		ADDITIONAL FUNCTIONALITY		ACCESSIBILITY		COMMUNICATION		CONTENT	
	Sensory	Experiential	Sensory	Experiential	Sensory	Experiential	Sensory	Experiential	Sensory	Experiential
Sample size	8	8	9	9	7	7	8	8	3	3
Mean	21,875	8,125	8,889	21,111	11,714	18,286	6,125	23,875	3,667	26,333
Standard Dev.	6,446	6,446	3,723	3,723	2,430	2,430	3,603	3,603	2,082	2,082
Degrees of freedom	14		16		12		14		4	
t	4,266		6,964		5,059		9,853		13,336	
p -value	0,001		3,191E-06		0,00028		1,122E-07		0,00018	
	Ho refused		**Ho refused**		**Ho refused**		**Ho refused**		**Ho refused**	
	Sensory		**Experiential**		**Experiential**		**Experiential**		**Experiential**	

Table 4.11: t-test results for Streaming Service for Roskos updated model.

In case of Shao dimensions, when speaking about Streaming Services (Table 4.12), the null hypothesis is not refused in case of Navigation dimension.

For the remaining two dimensions the results are:

- *Interactivity*: is correlated to the *Experiential* component;
- *Information*: is correlated to the *Experiential* component.

	INTERACTIVITY		NAVIGATION		INFORMATION	
	Sensory	Experiential	Sensory	Experiential	Sensory	Experiential
Sample size	10	10	17	17	8	8
Mean	6,700	23,300	15,412	14,588	8,500	21,500
Standard Dev.	3,889	3,889	7,977	7,977	4,751	4,751
Degrees of freedom	18		32		14	
t	9,545		0,301		5,473	
p -value	1,819E-08		0,765		8,216E-05	
	Ho refused		**Ho not refused**		**Ho refused**	
	Experiential		**-**		**Experiential**	

Table 4.12: t-test results for Streaming Service for Shao model.

Navigation dimension new division

Given that the null hypothesis is not refused only in case of "Navigation", a further analysis is performed for this dimension.
If compared to the other categories and dimensions, the amount of indicators associated to "Navigation" is much higher, also because of the low number of Shao dimensions to which indicators could be associated by respondents. During the interviews, indeed, several respondents stated that three dimensions were not enough and that for some indicators there seemed not to be a dimension fully matching the indicators characteristics.

For these reasons a new division for Navigation dimension is proposed, considering on one hand indicators related to the layout and on the other hand indicators related to the usage of the artefact:

- *Layout*: It concerns the ease of use and intuitiveness related to the layout of the digital artefact.
- *Usage*: It concerns the ease of use and intuitiveness related to the usage of the digital artefact.

As shown in Table 4.13, which reports the results of the t-test for the two components defined, now the null hypothesis is refused in both cases. In this way, Navigation category can be divided into two components: one associated to *sensory* affordances (*layout*) and one associated to *experiential* affordances (*usage*).

NAVIGATION - Layout		
	Sensory	Experiential
Sample size	8	8
Mean	21,625	8,375
Standard Dev.	6,948	6,948
Degrees of freedom	14,0	
t	3,814	
p -value	0,002	
Ho refused		
Sensory		

(a) Navigation - layout.

NAVIGATION - Usage		
	Sensory	Experiential
Sample size	9	9
Mean	9,889	20,111
Standard Dev.	3,480	3,480
Degrees of freedom	16	
t	6,231	
p -value	1,201E-05	
Ho refused		
Experiential		

(b) Navigation - usage.

Table 4.13: t-test results for Navigation dimension after the division into two components.

Conclusions on categories and dimensions allocation to sensory and experiential component

The results emerged from this case study were then compared with the results of previous works, as summarized in Table **??**, where:

- "state of art": refers to the evidences of previous thesis works;
- "evidence statistically derived from data on indicators": refers to the results emerged from the t-tests on music CD and Streaming Services;
- "explicit statements of interviewers": refers to the results of Section 5 of the questionnaire, where respondents were asked to allocate the categories/dimensions to the sensory or experiential component.

		BASIC FUNCTIONALITY	ADDITIONAL FUNCTIONALITY	ACCESSIBILITY	COMMUNICATION	CONTENT
State of art		Sensory	Experiential	?	Experiential	?
Evidence statistically derived from data on indicators	**CD**	Sensory	Experiential	Sensory	-	Experiential
	Streaming Service	Sensory	Experiential	Experiential	Experiential	Experiential
Explicit statements of interviewers		Sensory	Experiential	50% of sample for both	Experiential	Experiential

(a) Roskos updated categories.

		INTERACTIVITY	NAVIGATION	INFORMATION
State of art		Sensory	?	Experiential
Evidence statistically derived from data on indicators	**CD**	Sensory	Sensory	Experiential
	Streaming Service	Experiential	?	Experiential
Explicit statements of interviewers		Experiential	Experiential	Experiential

(b) Shao dimensions.

Table 4.14: Comparisons of the allocation of categories/dimensions to the sensory and experiential component.

In the following, a short analysis is performed for each category/dimension:

- **Basic Functionality**: Results are always in line with previous works; therefore it can be associated to the *SENSORY* component.
- **Additional Functionality**: Results are always in line with previous works; therefore it can be associated to the *EXPERIENTIAL* component.

- **Accessibility**: For this category the allocation in previous works was not clear, since in some cases it resulted sensory and in others experiential. Even in this case it results sensory for music CD, and experiential for Streaming Service. Also from the analysis of the explicit statements of interviewers it is not possible to associate it uniquely to one component, given that 50% of respondents allocated it to the sensory component and the other half to the experiential one.
  A unique association cannot be given to this category and this is reasonable since accessibility, related to the ease of interface with the artefact, is related to different characteristics of the artefact, which are specific for the artefact itself. Therefore, the association of this category is *case specific*.

- **Communication**: Results are always in line with previous works; therefore it can be associated to the *EXPERIENTIAL* component.

- **Content**: In previous works the allocation was not clear, given that in some cases it resulted sensory and in others experiential. Anyway, after the analysis of this case study, it can be stated that it is *EXPERIENTIAL*.

- **Interactivity**: In the theoretical model it was associated to the sensory component. In this case, for music CDs it is line with previous evidences, but in case of Streaming Services it is not; the same result emerges also by respondents answers.
  The allocation of this dimension to the experiential component seems reasonable, given the nature itself of the dimension, which implies an interaction with others. This also emerges by simply looking at the indicators associated to the category.
  For the analysis of previous works it should be underlined that in that case it was asked to associate the indicators to the artefact or to the service, which is different from the association to sensory or experiential component. Moreover, in the case study on Bim-Based systems the null hypothesis was not refused.

- **Navigation**: This dimension has been divided into two parts: one related to the *SENSORY* component and one related to the *EXPERIENTIAL* one.

- **Information**: Results are always in line with previous works; therefore it can be associated to the *EXPERIENTIAL* component.

4.5 Step 5: Affordance identification

Affordances identification has been performed in line with the identification of affordance indicators, by looking at the flowchart and the system architecture identified in Step 2 and 3 of the model, by considering the main usage of the two artefacts, and by taking into account also unusual uses, in particular for music CDs.
The identification of affordances has followed the methodology identified in the work of (Perpignano, 2020): in line with the criteria identified in (Evans, 2017) and according to the work of (Chenyi Chen, 2015).
A list of the affordances with their identification number, for Music CD and Streaming Service, are provided in Tables 4.15 and 4.16.

Music CD	
Affordance into grasp it	A1
Affordance with insertion on a device	A2
Affordance into refer a content	A3
Affordance with content management	A4
Affordance with payment	A5
Affordance into interacting with other systems	A6
Affordance into reflect light	A7
Affordance into cut something	A8
Affordance with drawing	A9

Table 4.15: List of affordances for music CDs.

Streaming Service	
Affordance into search a song/album/artist/podcast	A1
Affordance into refer a song	A2
Affordance with new releases	A3
Affordance with personal listening	A4
Affordance into navigating the website/application	A5
Affordance into interaction with others	A6
Affordance with system performance	A7
Affordance in user account	A8
Affordance with data management	A9
Affordance with payment	A10
Affordance with find a solution	A11

Table 4.16: List of affordances for Streaming Services.

4.6 Step 6: Construction of the incidence matrix

In Step 6 the incidence matrices have been constructed, by associating to each affordance the affordance indicators that originate the perception of that affordance. The matrices have been reported in Tables 4.17 and 4.18, where affordances and affordance indicators are represented with their identification number in the rows in *green* and in the columns in *light-blue* respectively.

	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14	I15	I16
A1	x		x	x	x											
A2	x	x		x		x										
A3							x	x	x							
A4										x			x	x	x	x
A5											x	x				
A6													x	x		
A7		x	x	x												
A8	x				x											
A9	x															

Table 4.17: Incidence matrix for music CD.

	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14	I15	I16	I17	I18	I19	I20	I21	I22	I23	I24	I25	I26	I27	I28	I29	I30	I31	I32	I33	I34	I35
A1							x	x										x		x	x	x					x								
A2							x	x										x			x	x	x				x					x			
A3					x	x							x					x																	
A4							x	x			x	x						x					x				x								
A5	x	x	x											x	x			x												x	x				
A6				x															x			x		x				x	x			x			
A7									x	x																									x
A8																x	x							x	x								x		
A9									x																x								x		
A10																													x						x
A11					x	x										x	x								x				x						x

Table 4.18: Incidence matrix for Streaming Service.

4.7 Step 7: Evaluation of affordance indicators

In Step 7 the evaluation of the affordance indicators have been performed, for the Streaming Service Spotify. A second questionnaire has been submitted to 30 respondents, asking to associate a value to each indicator:

-1 if perceived negatively, +1 if perceived positively, 0 if unable to provide an evaluation. Then, it has been associated an evaluation to each indicator, considering the value with maximum frequency (Table 4.19).

INDICATORS	-1	0	+1	EVALUATION
Text font	3	16	11	0
Text color	0	16	14	0
Text dimension	3	9	18	1
Sharing system	0	8	22	1
Notification system	12	10	8	-1
Email	11	12	7	0
Favourites	0	3	27	1
Personalized playlists	0	3	27	1
System settings	5	15	10	0
Language settings	0	18	12	0
System for playlist creation	0	10	20	1
System for songs removal from playlist	2	7	21	1
Follow artists	0	10	20	1
Button design	0	8	22	1
Icon shape	3	8	19	1
For free with advertisement	19	9	2	-1
Subscription	2	5	23	1
Home structure	3	7	20	1
Device connection	5	1	24	1
Results sorting	4	6	20	1
Search function	9	14	7	0
Voice connection	1	5	24	1
Download (song/album/podcast)	1	5	24	1
Number of users	7	13	10	0
User profile	2	9	19	1
Lyrics	5	0	25	1
Library structure	3	11	16	1
Collaborative playlist	0	10	20	1
Help desk	0	24	6	0
Clip video	7	13	10	0
Album cover/ Artist photo	0	6	24	1
System for pausing/ changing song	0	2	28	1
Follow other users	2	15	13	0
Data synchronization	2	7	21	1
Payment method	2	9	19	1

Table 4.19: Evaluation of affordance indicators for Streaming Service Spotify.

4.8 Step 8: Evaluation of affordances

4.8.1 Spotify Evaluation

After the evaluation of affordance indicators, it has been proceeded with the evaluation of affordances. The evaluation has been performed considering the indicators associated to each affordance as shown in the incidence matrices defined in Step 6. In particular, it has been made the weighted sum of the values associated to each indicator.

Table 4.20 reports, for each affordance, the number of associated affordance indicators, the number of indicators whose evaluation has been -1 or 0 or +1 and the overall evaluation of the affordance. As shown in the last column, whose colors represent the possible criticality, shifting from green to red, no value is highly critical, but a focus should be put on affordance A11 (affordance with find a solution), given the value close to 0.

AFFORDANCE	NAME	N° OF COSTITUENT INDICATORS	N° OF INDICATORS WITH -1	N° OF INDICATORS WITH 0	N° OF INDICATORS WITH +1	EVALUATION
Affordance into search a song/album/artist/podcast	A1	7	-	1	6	0,857
Affordance into refer a song	A2	8	-	1	7	0,875
Affordance with new releases	A3	4	1	1	2	0,250
Affordance with personal listening	A4	7	-	-	7	1
Affordance into navigating the website/application	A5	8	-	3	5	0,625
Affordance into interaction with others	A6	7	-	4	3	0,429
Affordance with system performance	A7	3	-	2	1	0,333
Affordance in user account	A8	5	1	1	3	0,4
Affordance with data management	A9	3	-	1	2	0,667
Affordance with payment	A10	2	-	1	1	0,5
Affordance with find a solution	A11	7	2	2	3	0,143

Table 4.20: Evaluation of affordances for Streaming Service Spotify.

4.8.2 Association of affordances to sensory/ experiential component

In Section 2 of the questionnaire it was asked to associate each affordance indicator to the sensory or experiential component. Starting from these results, each affordance has been associated to the sensory or experiential component, by considering the association of the indicators constituting that affordance, starting from the incidence matrix defined in Step 6 (Tables 4.21 and 4.22).

Music CD		
AFFORDANCE	EVALUATION	CONSTITUENT INDICATORS
Affordance into grasp it	Sensory	I1, I3, I4, I5
Affordance with insertion on a device	Sensory	I1, I2, I4, I6
Affordance into refer a content	Experiential	I7, I8, I9
Affordance with content management	Experiential	I10, I13, I14, I15, I16
Affordance with payment	Sensory	I11, I12
Affordance into interacting with other systems	Experiential	I13, I14
Affordance into reflect light	Sensory	I2, I3, I4
Affordance into cut something	Sensory	I1, I5
Affordance with drawing	Sensory	I1

Table 4.21: Evaluation of affordances for music CDs.

Streaming Service		
AFFORDANCE	EVALUATION	CONSTITUENT INDICATORS
Affordance into search a song/ album/artist/podcast	Experiential	I7, I8, I18, I20, I21, I22, I27
Affordance into refer a song	Experiential	I7, I8, I18, I21, I22, I23, I27, I32
Affordance with new releases	Experiential	I5, I6, I13, I18
Affordance with personal listening	Experiential	I7, I8, I11, I12, I18, I23, I27
Affordance into navigating the website/application	Sensory	I1, I2, I3, I14, I15, I18, I30, I31
Affordance into interaction with others	Experiential	I4, I19, I22, I24, I28, I29, I33
Affordance with system performance	Experiential	I9, I10, I35
Affordance in user account	Experiential	I16, I17, I24, I25, I34
Affordance with data management	Experiential	I9, I24, I34
Affordance with payment	Experiential	I29, I35
Affordance with find a solution	Experiential	I5, I6, I16, I17, I25, I29, I35

Table 4.22: Evaluation of affordances for Streaming Services.

4.8.3 Conclusions on affordances evaluation

As shown in Tables 4.21 and 4.22, in case of the music CD (digital product) affordances are mainly sensory, while in case of the Streaming

Service (digital service) they are almost exclusively experiential.

It can be therefore stated that, when shifting from digital product to digital service, *the amount of Sensory affordances decreases, while the amount of Experiential affordances increases, non proportionally.*
This evidence has been represented in Figure 4.23.
It shows also how in case of non-digital products affordances are almost exclusively sensory, while when shifting to non-digital services, experiential affordances prevail.

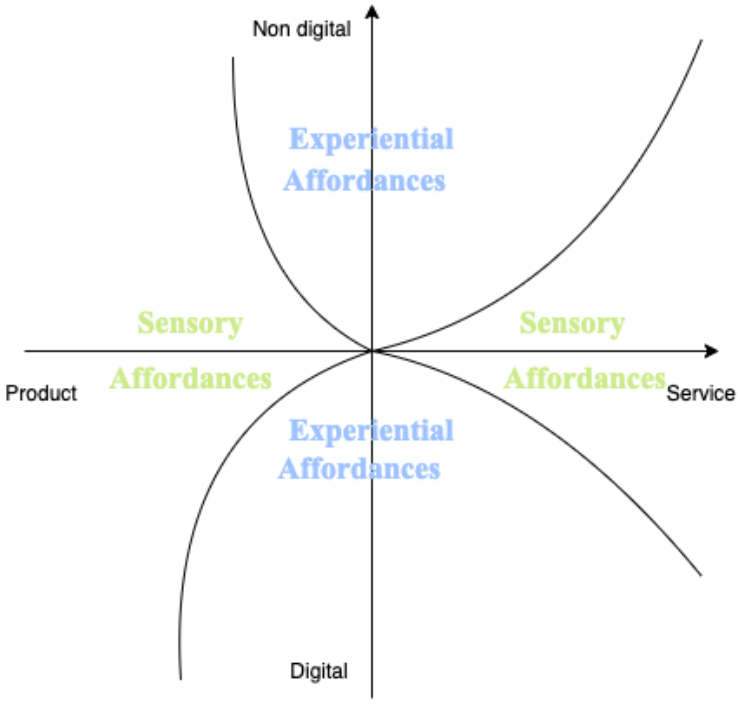


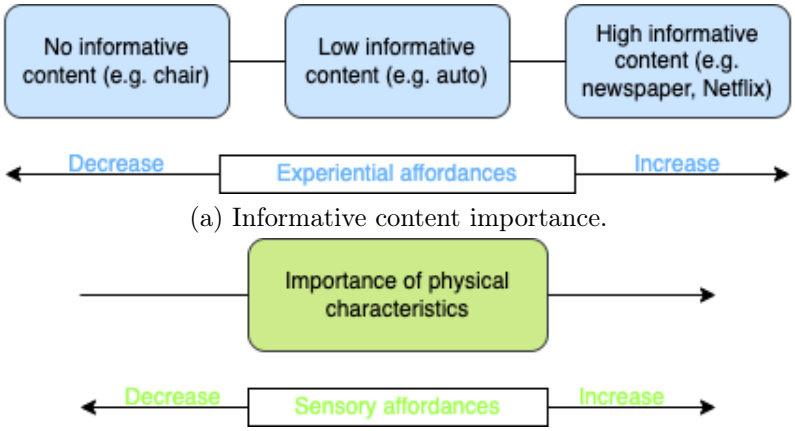
Table 4.23: Graph showing how affordances change when dealing with different types of artefacts.

By observing the experiential affordances of the music CD, the evidence is that these affordances are all related to data: the presence of experiential affordances therefore also depends on the *informative content.* (Figure 4.10).

Therefore, it can be made a distinction considering:

- the presence of informative content;
- the amount of informative content;

– the importance of the physical characteristics.



(a) Informative content importance.

(b) Physical characteristics importance.

Figure 4.10: Relationships between affordances and informative content/physical characteristics of the artefact.

4.9 Final discussion on case study results

In the case study two different digital artefacts have been analyzed. In this way, it was possible to overcome one of the main limitations of previous works: the focus on a single artefact, which is the food delivery application.
This case study allowed to have major insights on the main focus of previous works, that is to say the association of affordance indicators to sensory and experiential component, as analyzed in Section 4.4 of the document.

By comparing the results on affordance indicators for the music CD and the music Streaming Service, some distinctions already seem to emerge for the two artefacts. In particular, while for the digital product (the music CD), the association of the categories/dimensions is almost halfway between sensory and experiential component, for the digital service (the music Streaming Service) the association is much more shifted towards the experiential component.

This first result is then confirmed also in the analysis of the affordances (Section 4.8 of the document), where it is evident that, when shifting

from digital product to digital service, the amount of sensory affordances decreases while the amount of experiential affordances increases, almost replacing the sensory one.

These evidences are in line with what emerges from the literature and from previous works. In the work of (Tiotto, 2022) it is indeed analyzed how sensory and experiential affordances should not be associated to the artefact of to the service, but to the different components of the artefact. In particular, sensory affordances should be related to the physical component of the artefact, while the experiential one should be related to the intangible component and to the characteristic of being an experience-good.

For this reason, in case of digital products, which are tangible objects with a material component, the presence of sensory affordances is of major importance. The intangible nature of digital services, instead, leads to a huge reduction of their importance: the presence of sensory affordances is associated mainly to the features related to the graphic design and the layout of the service.

When speaking about experiential affordances, their presence is for sure important in digital products, given that they have an intangible component (the bitstring) which allows to transmit, store and transfer information and given that, as digital services, they are also experience-goods, capable of interacting with other objects, humans and with the environment.
Digital services are instead experience-goods, immaterial and deriving from a customized and unique process. For this reason, when dealing with this type of artefacts, the main contribution is given by experiential affordances.

From this case study it therefore emerges how designers should focus on different types of affordances when dealing with the development process of different types of artefacts. If, in case of digital products, a major focus should be given to sensory affordances, when dealing with digital services it must be analyzed with much grater detail the role played by experiential affordances, given their prevailing presence.

5 Conclusions

The thesis work addresses the theme of digital affordance as key concept for the design of digital artefacts. The objective is to support research that aims at formalizing an approach to the design of digital artefacts by exploiting the analysis of perceptions arising from the interaction between a user and an artefact within a digital system.
In recent years there has been, indeed, an increasing interest toward the use of the concept of affordance in engineering design, given the first attempts to propose models for the development process based on the concept of affordance. Despite this, literature on the subject is still scarce, and with a limited focus on digital artefacts.
Digital artefacts are indeed characterized by unique properties that distinguish them from traditional ones, imposing on designers a new approach to their development process that is no longer waterfall but agile, increasingly incremental and iterative.

To reach the objective of the work, the model for affordance design in digital artefacts, already defined in precedent thesis works, has been resumed and analyzed. The model is divided into 9 steps to be followed to identify and evaluate affordances that characterize a digital artefact.
A focus has been posed on the results previously obtained in the fourth step of the model. This step is related to the identification of affordance indicators and their categorization into the updated categories (Roskos, 2017) (*Basic Functionality*, *Additional Functionality*, *Accessibility*, *Communication*, *Content*) and dimensions (Shao, 2020) (*Interactivity*, *Navigation*, *Information*) used to describe a digital system. In particular, it was analyzed the association of categories and dimensions to sensory or experiential affordances.
When dealing with digital artefacts, indeed, it has to be emphasized not only the role played by sensory perceptions, but also the one of perceptions related to the experience that the user undertake when interacting with the artefact. Therefore, two clusters of affordances have to be taken

into account: sensory affordances, arising before the user undertake an action with the artefact and pushing the user to undertake an action with it; and experiential affordances, manifesting themselves after an action has been undertaken and influencing future interactions between the user and the artefact. These two clusters were already present in traditional physical artefacts but, within a digital system, the experiential component plays a much larger role than its physical counterpart.

Given the ambiguous classification of some categories and dimensions, a new case study has been analyzed, with the objective of validating the already defined model for affordances evaluation in digital artefacts.
The case study focused on the analysis of two artefacts in the music industry: a music CD, representing a digital product, and a music Streaming Service, representing a digital service.

After the analysis of the main actors involved, of the interaction between the user and the artefacts and of the artefacts' architecture, a questionnaire has been submitted to 30 users, through interviews, with the objective of analyzing:

- affordance indicators belonging to one of the updated categories (Roskos, 2017) and dimensions (Shao, 2022) used to describe the digital system;
- categories and dimensions association to sensory or experiential affordances;
- the affordances that characterize the two artefacts.

After the update of the allocation of some indicators to the different categories and dimensions according to respondents' answers, a t-test analysis has been performed. The aim of the analysis was to verify whether the categories and dimensions could be uniquely associated to sensory or experiential affordances.

It emerged that *Basic Functionality* category can be uniquely associated to sensory affordances while *Additional Functionality*, *Communication*, *Content* and *Information* can be uniquely associated to the experiential ones.

For *Accessibility* category it does not emerge a unique allocation, given that this category is related to the ease of interface with the artefact, which is related to different characteristics specific for the artefact taken into account.

Also for *Interactivity* dimension it does not emerge a unique allocation but, the result emerging from the music Streaming Service, that is the association to the experiential component, is actually in line with the definition of interactivity, that includes communication and interaction with others.

Finally, given the too general definition of *Navigation* dimension, it has been decided to make a further analysis, distinguishing it into two components: one related to sensory affordances and one related to the experiential ones.

Subsequently, there have been evaluated the affordances that characterize the two systems. It emerged that, when shifting from digital products to digital services, the amount of experiential affordances increases while the amount of sensory affordances decreases. Moreover, the presence of experiential affordances also depends on the presence and on the amount of informative content that characterizes the artefact.

The results emerged from the case study are in line with what emerges from the literature and from previous works and highlight how the focus of designers should be put on different types of affordances according to the artefact they are dealing with.
In particular, given that sensory affordances are associated to the material component of the artefact, and given that digital products are tangible objects with a material nature, their presence is fundamental in this type of artefacts. Digital products are also experience-goods and characterized by an intangible component, therefore also experiential affordances should be taken into account in their design process.
Digital services are instead immaterial by nature, and this is why, when dealing with their development process, designers should analyze with much greater detail the role played by experiential affordances, which represents the main contribution allowing the interaction between the user and the artefact.

The work, despite the limited importance, aimed at the enrichment of the research work on the concept of affordance applied to digital artefacts. By reviewing and proposing an approach for the identification and analysis of affordances in digital systems, this work would like to provide useful tools and support to designers for the development of digital artefacts, highlighting how affordances represent an added value for the usability of the artefact, suggesting to users actions and functions, through sensory and experiential affordances.

Limits of the study

One of the main limitations of the work is the number of respondents of the questionnaire. In order to make the sample as representative as possible it is advisable to expand the number of respondents to a number higher than 30.

A subsequent analysis might also take into account the importance of indicators, given that in different types of artefacts there may be categories and dimensions that are of primary importance, and others whose importance is only limited.

It might be also analyzed whether affordances can be grouped into clusters.

Finally, it must be considered that the evaluation of affordances has been indirect, given that it is derived from the evaluation of the affordance indicators.

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