Digital Artefacts and the Role of Digital Affordance

INTERNATIONAL DESIGN CONFERENCE - DESIGN 2022
https://doi.org/10.1017/pds.2022.2

Digital Artefacts and the Role of Digital Affordance

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Abstract

This work investigates how the concept of affordance should be revised following the digital evolution. Starting from a review of the literature about affordance, the most acknowledged constructs are compared with the variegated definitions of digital artefacts. The paper proposes a definition of digital affordance, overcoming the inconsistencies identified in the literature. The study is enriched by a series of interviews to investigate the final users' perception of affordance. Finally, the paper shows the application of the proposed model with a case study related to food delivery services.

Keywords: user-centred design, human behaviour, smart products engineering, affordance, digital design

1. Introduction

Digitalisation is increasingly pervasive and has represented the main source of innovation for the last two decades, since a higher number of digital than physical (non-digital) innovations occurred. This led to valuable changes shown between digital vs. non-digital artefacts, also in their design processes (Cantamessa et al., 2020). Among the changes implied by digitalisation in the design process, the present work focuses on the concept of affordance, since the users' behaviour and interaction with an artefact are strongly affected by the nature of the artefact (Normann, 1988).

Despite the richness of the literature on affordance, the available models do not seem adequate to be applied to digital systems. Accordingly, the paper proposes a definition of digital affordance, considering the features and elements of the artefacts. Recognise features of digital affordances helps to pose the bases to develop a model that could recognise and assess them. Then, the ultimate goal will be supporting designers in the development process of digital artefacts (Hartson, 2003; Kaptelinin, 2012), in particular during the definition of the product architecture at the system level design phase.

Indeed, a broader use of affordances for design could allow companies in the identification of new combinatorial affordances and be useful for describing human-product interactions (Pucillo & Cascini, 2014). Moreover, the design of digital artefacts is more and more complex requiring a specific knowledge for the correct implementation of the digital features, such as digital affordance. The literature review in Engineering Design highlighted several different results related to the concept of affordance, neglecting its evolution into digital artefacts. Moreover, several models to evaluate affordance have been developed in the literature. The literature shows a gap also in the definition of digital artefacts, with a discussion widely open in Information Systems (IS, Kallinikos et al, 2013).

In the present work, the different interactions with digital artefacts, distinguished from the no-digital and pure-digital artefacts, are analysed starting from the definition of digital artefacts, both products and services, leading to the characterization of the 'digital affordance'. The validation of the identified features has been carried out through the definition of a model to investigate how users' behaviour changes when they interact with a digital artefact. Starting from a model developed to evaluate

e-learning platform (Roskos et al., 2017), a revised version generally applicable in digital environments has been developed. It, in the end, aims to evaluate if digital affordance is distinguishable from the traditional one based on the nature of digital artefacts.
The investigation method adopted some steps from the literature, with a specific reference to the 'affordance indicators' proposed by Chen (2015) and Roskos et al. (2017). The proposed model is built on evaluating usability to assess affordance, identifying the perceptive and emotional aspects related to a user experience. Thus, this perspective allows to focus on the categories of affordances associated with sensory perceptions and actions. To validate the model, a case-study focused on a food-delivery service has been studied. This case study is still preliminary and not all the methodological steps are covered; however, interesting evidence has been collected from associating affordance elements to specific categories and to the tangible or intangible aspects of an artefact.
The paper, firstly, analyses the state of the art on affordance, followed by the concept of digital artefacts to highlight the limitations of the traditional definitions of affordance in capturing the elements that are activated by the digital nature of artefacts. Then, the concept of digital affordance is characterized and validated by discussing the empirical evidence collected through the case-study. Conclusions on the general contribution of the present work and suggestions for further studies are presented at the end.

2. Affordance and its evaluation

The concept of 'affordance' is considered essential for the design activity (Maier & Fadel, 2009). The term affordance was defined for the first time in Psychology as "*what it* [the environment] *offers the animal, what it provides or furnishes, either for good or ill*" (Gibson, 1979). Accordingly, affordances are enabled by physical characteristics (size, surface, material, etc.) establishing a relationship of complementarity between artefact and animal, using senses (sensory perception). The concept of affordance was formalized as the users' sensory perception of the relationship that is established between themselves, the artefact and the surrounding environment (Gibson, 1979). Successively the term 'affordance' was applied to Design (Norman, 1988), where it is linked to the user's interpretation of the artefact through knowledge and previous experience. The interpretation can lead to 'real' or 'perceived' affordance: the former refers to the real properties of the artefact, the latter to the perceived properties, which may not be determined by the usability.
In Human-Computer Interaction (HCI), affordances have been considered as the world properties enabling some actions to an organism equipped to act specifically (Gaver, 1991). Organisms, in particular animals, deduce a "compatible configuration" between the object attributes and themselves, representing their way of acting. The compatibility is evaluated and expressed through the information perceived by the animal. For these reasons, affordances are categorised as *perceptible*, *false*, *hidden*, or a *correct rejection*. The concept has been reformulated several times (Pols, 2012) and numerous definitions were developed (Jenkins, 2008; Evans, 2017).
In Design, the physical nature of affordance is highlighted with two categories: 1) 'perceived' if about the perception of characteristics that allows its correct functioning; 2) 'physical' if it is generated by the physical characteristics of an artefact (Normann, 1999). Then, perception and action have been considered inextricable, as well as the user and the environment (Overbeeke et al., 2002). The affordance could be adopted to understand the relationships among technical functions and user tasks (Galvao & Sato, 2005), or as the relationship between an artefact structure and a user (Leonardi, 2013), thus determining the behavioural results in a specific context. Therefore, affordance is referred to the wide set of functions and constraints enabled by an artefact in a specific environment, being the dynamic connection between users and artefacts (Davis, 2016), also considering the intrinsic nature of the artefacts.
Finally, the study of affordance from the IS perspective reached the definition of the 'technological affordance', [as] an action potential, that is, to what an individual […] with particular purpose can do with a technology or information system", considering the dynamic interactions between people and the technologies they use.
In the last two decades, the main trend in the analysis of affordance is to identify differences and categories among the affordances. Different terminologies, categories without a clear explanation are

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in this literature, generating a lot of confusion (Evans, 2017); the definitions and interpretations reported here are not exhaustive, but Figure 1 depicts an overview. Overall, the gap in the literature is the lack of a comprehensive approach that brings together advances in the affordance theory from the different domains. The first attempt to bridge this gap derive from the IS literature, introducing meta-features of affordances. These constitute a static affordance framework to anticipate how affordances are perceived and they evolve when modular IT or IS systems are involved.

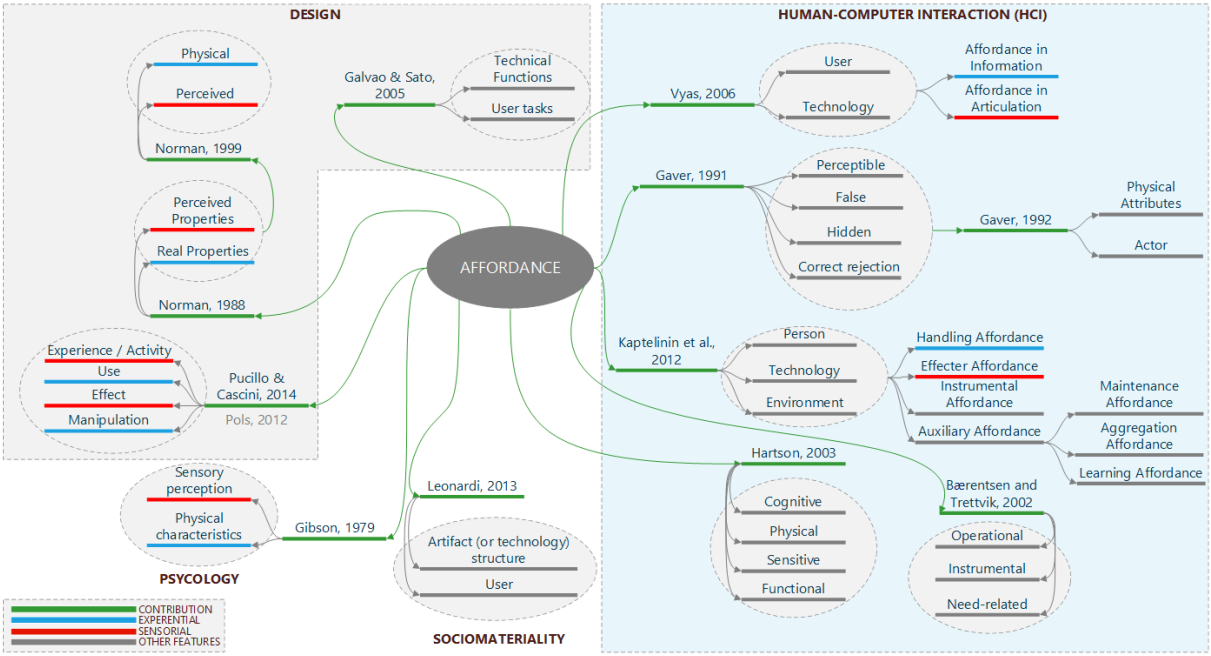

Figure 1. Conceptual Map of Affordance Definitions

3. Not-Digital, Digital and Pure-Digital Artefacts

The literature on the definition of digital artefacts is again not clear and univocal (Kallinikos et al., 2013), in the domain of IS. A digital artefact is often considered as any material or immaterial object, based on a digital technology that allows data collection, processing and/or transmission. The intangible nature and computing architecture are crucial elements implied in digital artefact; they differentiate them from non-digital ones providing flexibility and "re-programmability" with low costs (Faulkner et al, 2010). Structural constraints are more flexible and continuous improvement of the designed object are provided (Yoo et al, 2010). By combining this 'agnostic nature' of physical modules and the re-programmability of digital components, through layered modular architectures, in fact components can be added or re-combined without any constraint (e.g., interface sizing, Yoo et al., 2010). This enables the addition of new behaviours after the product has been produced and sold and it implies that, as a software platform, the structure and the physical parts must be designed to be ex-ante enabled so to accept ex-post behaviours. A new component, software, but not necessarily, can be ex-post added to enable behaviours and previously unimagined physical features (i.e., forms).

Sometimes, digital artefacts are also related to cyber-physical devices that not only show software-based capabilities, but also have a relevant physical nature (Vitali et al., 2017). They are physical products empowered by digital technologies, which enable programmability, communicability, memorability, sensitivity, traceability, and associability (López et al., 2011). Such digital artefacts have, therefore, 'intelligent capabilities' that allow them to achieve some elements of behaviour, typical of an intelligent being (Wong et al, 2002), expressed by communication, sensing processing and network capabilities (Kawsar et al, 2010). They can become deliberative, reflectional, experiential and communicative agents of reflection for behaviour change (Ghajargar et al. 2017), leading to be distinguished from the 'pure-digital' artefacts. Pure digital artefact in fact are referred to an only digital (such as e-mail), intangible,

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copiable and not unique nature, makeable by end-users, based on signals and codes, located in a computing (local or remote) memory and accessible only by artefact that are digital.
In this study, we intend to highlight the differences between physical and pure-digital features of a digital artefact, intended as a cyber-physical system, capable to collect, elaborate and transmit data, interact with other physical and/or digital objects, humans, environment and possibly participate in decision-making-processes.
Figure 2 represents the extension of the traditional concept of affordance once the distinction between physical and digital enviroments is applied.

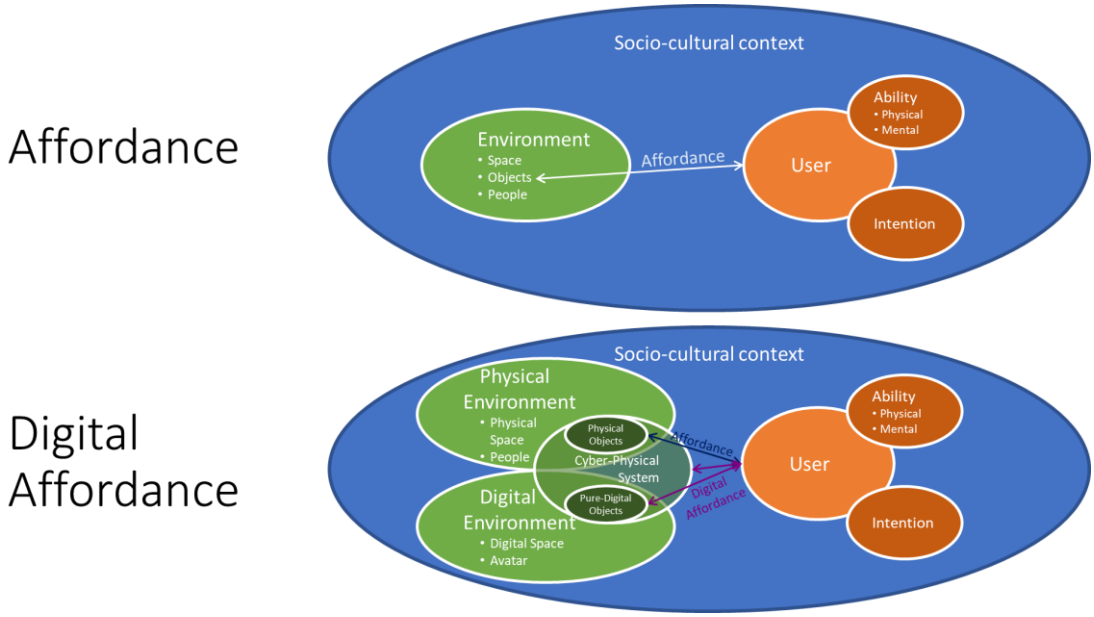

Figure 2. The evolution of the concept of affordance, from tangible objects (above) to digital and cyber-physical systems (below).

4. Digital Affordance

The interactions between user and artefacts cannot be considered independent from the nature of the artefact (Davis, 2016). In the characterization of interactions, different perspectives are adopted in the literature (Jung et al., 2017): (i) *semantic*, the artefact as a carrier of intended meanings; (ii) *cognitive*, the representation of user mental model; (iii) *material*, the presence influential in the lived world.
The role of data, information and context is evident (Hartson, 2003) and interfaces are the means through which user interacts with digital artefact (Sun, 2014; Rapp, 2015). Then, as highlighted in the HCI literature and differently from no-digital ones, most of the affordances of digital artefacts occur through perceptions the user has when relating to the digital interfaces (Davis, 2016).
Moreover, digital artefacts, due to their layered modular architecture (Yoo et al, 2010), present internal hierarchies of functional elements, enabling hierarchical affordances. The new concept of 'nested affordance' represents such multiple affordances: they are linked to each other through a relationship (Faulker, et al. 2010) or a cluster of affordances, which can be hierarchically defined. All these considerations change the definition of the set of attributes that characterises digital affordance with respect to traditional conception (see Table 1).

Table 1. Features of the Digital Affordances

	Description	*Author(s)*
Nested Affordances	Grouped in space. They are linked through functional or hierarchic relationships.	Gaver, 1991.
Depending on the information context	The quality of the perception depends on the level of perceptible information	Hartson, 2003; Brown, 2005; Jenkins, 2008.

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Goal-Oriented	Clustered by the actor's specific aims. They lead the actor's perception in the choice and interpretation processes.	Scarantino, 2003; Brown, 2005; Pucillo & Cascini, 2014.
Subject to flexible design constraints	Channelling information required for the correct interpretation	Majchrzak & Markus, 2012
Sensory	Intervening on the actions that are to be taken. Their timing is ex-ante the interaction and are usually associated with architecture	Gibson, 1977; Norman, 1999.
Experiential	Involved in the future interactions with the actor. Their timing is ex-post the interaction and are usually associated with services.	Chen, 2015; Kaptelinin, 2012; Pucillo & Cascini, 2014.
Linked to indicators	Strongly associated with one, or more, specific designed element	Chen, 2015; Evans, 2017
Distributed among categories	Affordance categories express intrinsic differences. Interactions with Administration and Tool are introduced.	Roskos, et al. 2017

5. The validation of the elaborated concept of digital affordance

The need of a characterisation of affordances considering the features of artefacts, specifically in digital circumstances, is here addressed through an evaluation model. It has been revised from an existing model adopted for e-learning platform (Roskos, et al., 2017); it employs clusters of affordances and affordance elements (i.e., Functionality, Communication, Accessibility, Content, Administration, and Tools), as well as for multiple affordances.

5.1. The model for Digital Affordance validation and evaluation

To evaluate the characterization of the digital affordances, a deep understanding of the whole ecosystem is required. Starting from a general analysis, then an evaluation and validation process is structured to identify affordances and their elements, in the context of users' interactions. The validation and evaluation process follow some pre-defined steps[1]:

1. Identification of the actors, outlining their profile, objectives and interactions with the artefacts;
2. Flowchart modelling (e.g. through UML) of the use action progressing;
3. Definition of the digital system architecture, through block diagrams, to show the modules and their elements, to analyse the information workflow, how the system works, how the various modules functionally interact. The architecture representation highlights also the order among modules and elements, as indicator of the hierarchy among affordances;
4. Identification of the affordance indicators and grouping them in categories (Functionality, Communication, Content, Accessibility Administration, Tools; Roskos, et al., 2017);
5. Identification of the affordances, starting from the functional structure of the system, expressed according to their relationships (Maier, 2009, Evans, 2017), consistently with methodology and criteria presented in literature (respectively Chen, 2015; Evans, 2017);
6. Construction of the incidence matrix, filled following the interactions among the indicators, on the columns, and the affordances, on the rows; the matrix allows to associate each affordance indicator to the referred affordance;
7. Evaluation of the affordance: the evaluation took place using the Guttman scale (Guttman, 1944): +1 if the perception of the element is positive; 0 if you are not able to give an evaluation to the element; -1 if the assessment of perception is negative;

[1] For a deeper and clearer understanding and replicability of the methodology see https://webthesis.biblio.polito.it/17740/

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8. Final affordance assessment using the incidence matrix and the evaluation of affordance indicators, identifying affordances perceived negatively and understanding which aspects of the system would impact. Then, these affordances should be sorted onto the artefact and service, making possible to understand whether sensory or experiential perception prevailed and therefore on which component of the digital system designers should intervene;

5.2. The case study: a digital system for food delivery

The case study adopted for the investigation of digital affordance is here represented by a digital system for food delivery. Most online food delivery services aim to provide an intermediary service between consumers and restaurants, using delivery force, but they are not liable for the actual food preparation. Food delivery systems are reachable through web portals or applications, by PCs or smartphones. These systems usually offer a personalised account for customers, restaurants and deliverers through which users experience the service. In brief, their service offered is structured as follow: customers log in and visit the main page, multiple options allow to reach the list of restaurants available for the delivery and their menu, then an order is placed and the payment defined (often by a digital payment system, such as online banks, but also by cash); then the digital system activates the restaurant to prepare the ordered items, the restaurant accept or reject the order; finally, if accepted, a deliverer (often a rider) is activated to pick up the items ordered and deliver them to customer's.

One major company of the Italian Food Delivery industry had to re-design the information workflow of its system to improve users' experience. The study of the involved affordances was a natural consequence. For the study, a meeting was conducted with technical experts, aiming to complete the knowledge on design-specific characteristics of the service and to recognize the list of functional modules, so then to arrange affordance indicators in each of these modules. Then, end-users have been interviewed. Being the interviewees 16, the sample does not lead to robust quantitative inferences, and only qualitative analyses were conducted. Interviewees were asked to complete the list of the selected affordance indicators, according to their experience to validate the association of the affordance indicators to the functional modules we made. These associations were made by considering the highest frequency of association per each affordance element to a functional module.

The further step of validation from the side of customers was conducted through two focus groups. The first involved 6 people, aged between 17 and 48. Participants were asked to evaluate their experience generally during their interaction with digital services, specifically food delivery and online shopping. No prior knowledge or experience with these services was required. The aim of this focus group was thus to validate the hypothesis on the similarities of perceptions among digital services and their usability. The users' standard perception would have been a step toward the generalization of the concept of digital affordance regardless of the specific digital artefact considered. Participants were asked to discuss around the same questions and topics. During each part, the investigation was meant to analyse the three moments of interaction (before, during and after use).

The second involved 8 people, aged between 19 and 51. Participants here instead were asked to evaluate their experience during their interaction specifically with the considered food delivery system. Differently from the previous one, all participants were required to have previous experience with food delivery services. The aim of this focus group was to identify the main drivers for usability. Thus, participants were asked to discuss specific questions, aimed at verifying the influence of the main elements on their experience with the considered food delivery system.

The interviews and focus groups were conducted through an online medium (Google Meet), because of Covid-19 restrictions which did not allow to organize them otherwise. Interviews and focus groups referred to different people. Participants in the focus group have been selected from the personal network of researchers, according to their education and work experience.

Then, a questionnaire was administrated specifically dedicated to testing step 3 and step 4. The questionnaire consisted of a total of 50 questions, one for each affordance indicator to be tested. This allowed validating the correct allocation to the clusters of Sensory Affordance (mainly, due to the artefact) or Experiential Affordance (mainly, due to the service), indeed, respondents were asked to relate each affordance indicator to the artefact or to the service. To minimize the acquisition of invalid data, a brief and simple description of each affordance element was provided, as well as the concepts

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of Artefact and Service, without ever explicitly writing the word "affordance", being an unclear concept to non-experts. The questionnaire was submitted to 185 people using food delivery apps on their smartphones or PCs. The sample was chosen as close as possible in percentage terms to that of the average age profile of the users of the largest Italian food delivery services. The respondents of the questionnaire were composed as follow: 54% were women and 46% men, all of them of Italian nationality and aged between 18 and 55 years. The sample was organized into four age groups: 18-25, 26-35, 36-45, 46-55; each of the bands corresponds respectively to 18.35% - 23.78% - 29.19% - 28.65% of the total. The respondents were equally distributed among North, Centre and South of Italy.

6. Results and Discussion

The above-described process first resulted in the identification of the actors involved (Step 1). Four main categories, their main reasons of action were crucial to be analysed to investigate their interactions with the digital systems. They were: (i) restaurants, with the possibility to reach further customers, a higher utilization rate of existing kitchen facilities, as well as the chance to build different relationships with customers; (ii) customers, with convenience advantages: greater and wider choice of food and restaurants, being informed in real-time on the status of the order; (iii) deliverers, with light and easy recruitment processes, freedom and flexibility (they are free of accepting or denying any orders), the amount of salary clearly linked to the effort (number of orders); (iv) platform owners, with the possibility to collect and manage customers, restaurants and deliverers, also improving the contents offered. These four categories of actors were confirmed by the literature on such services (Li et al., 2020).
Step 2 allows identifying the modules that are perceived by the users. The focus of the present work is limited to the modules perceived by customers, without considering the modules from the perspective of other actors. The customer journey and the scenarios of use were validated through the main four food delivery services in Italy. The main emerged scenarios are related to different actions, such as: a customer is very hungry and want the food immediately; a customer is making an order for another place/person; a customer is having problems with the order; the deliverer or the restaurant is late; the deliverer has problems in finding the customer's address; the platform owner is having problem in payment check. These are consistent with the ones identified in similar case studies. This step is the foundation to understand all the modules that are necessary to reach the expected objectives of a food delivery system (Step 3). The system represented through a block diagram (in Figure 1, and consistent with the diagrams from Trupthi, et al. 2019) consisted into a specific configuration of functional elements, which confirm also service can be considered as bundles of functional modules (Voss & Hsuan, 2009).

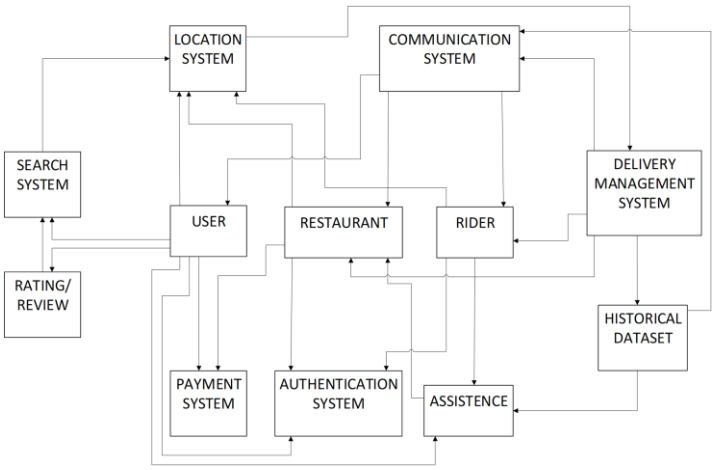

Figure 3. Block diagram representation of the considered food delivery system

This block diagram allows the analysis of the system functions, enabling the affordance analysis. Following the Step 4, a first list of affordance indicators was generated. They are listed in Table 2. The analysis of indicators of the affordance of the digital artefact is linked to the sensory outputs that the digital artefact generates (vibrations, flashing lights, images, etc.) and to the role that the graphic elements play (Roskos et al., 2017): buttons, icons, colours, position of the text. These elements are

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related to social conventions that represent an element that facilitates the interpretations of affordance (Hsiao, et al. 2012). The initial list of indicators is coherent with the indicators identified in the reference study (Roskos, et al., 2017) and adjusted to other inputs collected in the literature. Then, the adaptation of the list to the food delivery was performed. In particular, the affordance indicators related to the Content category (about the contents e.g. number of restaurants) were not considered relevant for the scope of the study, because end-users are not able to modify the menus of restaurants.

Table 2. The digital affordances indicators

Affordance Indicators									
Add a Review	Chart Editing	Chat	Colours and Fonts	Communication Evaluation	Delivery Monitoring	E-mail	Filters	Finalizing Orders	Help Desk
Multilingual	Notes on the order	Notifications	Order Results	Order Status	Orders History	Other Users' likes	Other Users' Review	Payment Methods	Phone
Preferences	Promotion	Rating Customer Care	Rating Restaurant	Rating Rider	Restaurant Information	Restaurant Localization	Rider Information	Rider Localization	Sharing
SMS	Sound Feedback	System settings	Text Dimension	User Account	User Localization	Vocal Commands			

The questionnaire finally allowed to investigate how the affordance elements were associated with a specific cluster of affordances and that association was referred to the artefact or the service. A two-tailed t-test with a 95% confidence interval was conducted verifying the null hypothesis (H0) that tests whether there are any differences the associations of specific affordance categories in the distributions of responses for the digital artefact ('Artefact') and the 'Service' part of the digital system.

Table 3. Statistical analysis of the cluster of affordances

	Functionality		Communication		Accessibility		Administration		Tools	
	Service	Artefact	Service	Artefact	Service	Artefact	Service	Artefact	Service	Artefact
AVG	39.40	145.00	48.80	131.00	124.33	59.33	112.20	72.20	139.00	42.67
St. Dev.	34.38		20.24		38.10		32.62		33.90	
Variance	1181.98		409.66		1451.61		1064.06		1149.21	
T value	4.86		6.42		2.09		1.94		3.33	
T des	2.306		2.306		2.776		2.306		2.776	
	H0 rejected		H0 rejected		H0 not rejected		H0 not rejected		H0 rejected	

Functionality, Communication and Tools demonstrated and confirmed the statistically significant difference in the distributions of the two answers. Functionality and Communication are strongly related to the Artefact, Tools to the Service. No significant differences have been detected for the Accessibility and Administration characteristics, showing a cognitive difficulty of the respondents in associating which indicator of the system (if they were from service or artefact) were determining that affordance.
This result represents first evidence of how affordance is not driven, in digital contexts, only by the perception and interaction with the physical elements of a system, going beyond the traditional perspective (Norman, 1999). This also demonstrates the presence of aspects associated with the role of information (Hsiao, et al. 2012) and therefore confirms the requirement to also consider interfaces (Tool) as an essential element of interaction as proposed by the HCI literature. Finally, the inability for the user to associate system elements to specific affordances (Administration and Accessibility) confirms the confusion to which digital systems can induce, as underlined by (Kallinikos et al., 2013).

7. Conclusion

The role of affordance is largely discussed in the literature, with different perspectives and approaches in the definition of affordance and the role they play into design processes. Moving toward digital systems, the concept of affordance has not been evolved and a lack of clear and effective definitions is extended also to the definition of digital artefact.
The present work is a preliminary contribution to the definition of affordance in a digital environment, through the new concept of digital affordance and its features. The research aims to step forward, but further studies are required to investigate and state the clear ontology of digital artefacts, with the potential to expand the concept also to cyber-physical systems. For the digital affordance concept, a

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preliminary characterization is presented here, but the plain understanding of this would require having clearer information about the users' interaction with a digital artefact. This would allow to define a model in the investigation of affordance in digital contexts and it would provide useful elements to designers considering the interactions between users and digital artefacts. Digital affordances in fact catch those modular layered architecture of digital artefacts that give flexibility and modularity to system level design and product improvement.
The main limitation of the present study is the specific focus of the case study on the food delivery segment. This could affect the generalisation of the results presented to different domains, which might imply non-identical perceptions and roles.

Acknowledgement

The authors thank E. Perpignano, M. Caridi and M. Franceschi for having contributed to the present work of research with their effort in data collection and by discussing and sharing their conceptual reflections.

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