TYPES OF AFFORDANCES AND THEIR ROLE IN QUANTITATIVE UX/UI RESEARCH. A SCOPING REVIEW OF AFFORDANCES-FOCUSED LITERATURE

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ABSTRACT

Human-computer interaction is one of the most prolific fields of the last decades, due to both the rapid technological developments and the increased mass availability of these developments. HCI is also a highly interdisciplinary field, which brings together researchers from engineering, computer sciences, psychology, sociology, and even fields like medicine, education, and arts and humanities, and makes use of a huge variety of quantitative, qualitative, and mixed research methods. One of the key constructs in technological design and in HCI is that of "affordances", introduced by the American psychologist James Gibson in the late '70s - early '80s. This construct underpins the design and development of almost all technological devices intended for human use and is central to what is nowadays known as user-centered design. However, it is exactly this complexity and interdisciplinary nature of the field that allows for a vast and sometimes worrying inconsistency in the guiding theories and research methods. Against this backdrop, and in alignment with the increased calls for reproducibility and clear research reporting, we performed a scoping review of quantitative primary research studies in UX/UI that focused on 'affordances' use and/or analysis. Our findings show a scarcity of studies that are thorough in reporting important information, such as clearly mentioning the research design, analysis methods used, measurements, procedure, and sample. Furthermore, another worrying aspect, acknowledged in previous studies, is the significant overlapping of the concept of "affordances" with that of (system/device) functionality. We hope that our review will be helpful for researchers new to the field or for those interested in searching for papers that place 'affordances' at their core.

KEYWORDS

Affordances, User Experience, User Interaction, Quantitative Research, Research Designs and Methods

1. INTRODUCTION

Our daily lives are being increasingly impacted by the tremendous development of technologies. The pervasiveness of technological devices makes it that most of us interact on a daily basis with a huge variety of electric and electronic devices, and rely significantly on them to function and interact in society, at work, or in the most personal and intimate areas of our lives. Not surprisingly, the design of these technologies influences how the user interacts with them, which has significant and substantial consequences, both for the individual and for the technology developer/manufacturer.

2. THEORETICAL BACKGROUND AND RATIONALE

One of the key concepts in technological design is that of 'affordances'. The term was introduced by the American psychologist James J. Gibson, to explain how organisms perceive the surrounding environment and the objects that populate it, how the associated meaning is built, and how action is taken based upon this

perception and meaning. In Gibson's original words, "The affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill" (Gibson, 1979, p. 127).

Attesting to its importance is that, albeit originating from psychology, the concept of affordances has found uses in other areas of science or professional practices. Beyond its origin grounds in ecological psychology, it can be encountered in more related sciences, like pedagogy (Chow et al., 2015; Meinel & Krohn, 2022), arts and humanities (Gieseking et al., 2014; Scarlett & Zeilinger, 2019), as well as in more distal fields, such as music (Clarke & Clarke, 2011), or political sciences (J. L. Davis, 2020). However, regardless of the field or discipline in which it is used, it almost always signals an interdisciplinary approach, like is the case, for instance, for neurophysiology's applications in, and implications for art and design (A. Chatterjee & Cardillo, 2022).

Concomitantly with its widespread and transdisciplinary adoption, we also witness a need for increased precision, substantial and consistent empirical support, and direct and unambiguous application (i.e., operationalization), especially in fields such as engineering and computer sciences. While visionary, Gibson's concept of 'affordances', as it was introduced, was nevertheless in its infancy and required more refinement, at least with respect to people's interaction with technology (see, for instance, Oliver, 2005, for an open call for clarity and appropriateness). Gibson, himself, most likely, had no way to foresee how impactful his 'affordances' hypothesis would become. Moreover, Gibson's perspective allowed for ambiguity in the meaning of affordances; "an affordance is neither an objective property nor a subjective property; or it is both if you like" (Gibson, 1979, p. 129).

Therefore, unsurprisingly, technological design was not only among the fields that most readily embraced the concept of affordances but it was also the field in which it found the most clearly defined applications (Khosrow-Pour D.B.A. & Bhattacharyya, 2021; Ling, 2004; Nardi, 1996; Sears & Jacko, 2007). With specific regard to human-computer interaction and the subsequent technological design of information processing devices, Donald (Don) Arthur Norman, is perhaps the most prominent researcher and leading figure. His work furthered the meaning of affordances and opened new avenues for research and practice, in UX and UI in general, and especially in what is known as 'user-centered design'. Specifically, while Gibson's conceptualization of affordances disregarded the human agent's role in determining if something is or is not an affordance (or, more precisely, limited it to identifying the affordances, i.e., the Gibsonian affordance is independent of the user, it either exists or not and the user either acknowledges and access it or not), Norman emphasizes the central and crucial role of the user's own interpretation in deciding if something is an affordance or not (Donald A. Norman, 1988; Donald A. Norman, 2013).

In technological design, the above-mentioned ambiguity in the Gibsonian acceptance of the meaning of affordances needed to be dealt with, since, arguably, it is realistically and objectively impossible for a technology developer to faithfully observe the 'objective-subjective' dualism of Gibsonian affordances straightforwardly. Don Norman's conceptualization elegantly and effectively addressed this issue, by including the human agent and agency in the building of the meaning of affordances. In Norman's conceptualization, the user's mental processing and models (which, in certain cases, can be pre-existing and/or culturally embedded/loaded) play a role in identifying the 'potential' affordances and in determining their status. Furthermore, the user also evaluates the ease of use of said affordances which ultimately decide the propensity for action (or 'actionability', for short). Finally, Norman's view allows for the user to even conclude (more or less as a 'stretch of imagination') that an affordance exists, even though, objectively, as a physical object, it does not.

The concept of affordances was significantly developed and refined after its introduction by Gibson. However, it is beyond the purpose of this paper to present a thorough and comprehensive review of these developments or of their applications in specific domains. In this respect, we warmly direct the reader to several excellent and thorough reviews, such as Chong and Proctor's (2020) On the Evolution of a Radical Concept: Affordances According to Gibson and Their Subsequent Use and Development, or Tabuenca et al.'s (2021) Affordances and Core Functions of Smart Learning Environments: A Systematic Literature Review on the characteristics of desirable affordances for smart learning environments, Ronzhyn et al.'s (2022) Defining affordances in social media research: A literature review, Xue and Churchill's (2019) A review of empirical studies of affordances and development of a framework for educational adoption of mobile social media, or Bahari's (2022) Affordances and challenges of technology-assisted language learning for motivation: A systematic review. These and other valuable reviews and meta-analyses did excellent scientific work in explaining the evolution of the conceptualization of *affordances* and their consequent use in technological design.

Nevertheless, while the theoretical bases of 'affordances' are relatively well covered in the literature, we could not find thorough and comprehensive reviews regarding the research methods and the methodologies used in affordance research. This, in itself, is not surprising, considering the highly interdisciplinary nature of the field and its rapid evolution, but it is a shortcoming when considering the calls for reproducible research. Therefore, against the above backdrop, we performed a literature review with a specific focus on quantitative research that was explicitly interested in affordances, and operationalized and modelled them as part of their analyses.

3. LITERATURE REVIEW

The databases covered by our search were Elsevier's Science Direct and Scopus, Springer Link, Emerald Journals, Wiley Journals, ProQuest, Taylor and Francis, Sage, Nature Journals, and Google Scholar* (with the notable mention that the latter was rather a starting point since it isn't a fully-fledged academic database and academic articles indicated by it were, in virtually all instances, indexed in one or several of the other, more established academic databases). This initial search yielded 3821 results, ranging from 1985 to 2023 (we did not impose a year limit), which, after filtering out the duplicated files and keeping only journal articles and conference papers, went down to 3465.

The second filtering implied searching for publications' texts for "quantitative" research and for "user experience (UX)" or "user interface (UI)". Specifically, in order to keep only studies reporting quantitative research, we used the Boolean phrase ("scale" OR "questionnaire" OR "inventory") to search the articles' main text, which resulted in 79 papers, that were manually processed for the information of interest. The aggregated Boolean query was "("scale" OR "questionnaire" OR "inventory") AND ("affordance") AND ("user experience OR UX" OR "user interface OR UI")". This second step kept a number of 1819 publications.

Our 3rd and final selection kept only papers that mentioned specifically the keyword "affordances" in their research questions (we filtered the text using regular expressions) and in which at least one of the constructs used in the model referred directly to affordances. Ultimately, a selection of 79 was kept to be individually processed for information extraction (including manually).

We excluded papers that used machine learning approaches (while promising in terms of delivering insights on users' behavior and predicting decisions, they do not derive meaning directly from the participants' responses, i.e., prediction is central, whereas the underlying factors/causes are not explicitly analyzed), and studies that did not measure/operationalized affordance clearly and/or did not provide quantifiable and verifiable associated validity and reliability indices.

Refining the search and filtering the initial selection or publications based on criteria like the type of publication (e.g., journal article, conference paper, book chapter, book, etc.), type of research (e.g., primary vs secondary), and by using the meta-data provided by the academic database (*e.g.*, abstracts, keywords, subject/discipline) is not only common practice in such reviews (Ronzhyn et al., 2022, and others; see, for example, Xue & Churchill, 2019), but it is rather necessary to identify relevant publications.

4. RESULTS

Out of the 79 studies that entered the manual extraction of information, only 26 studies meet all criteria of completeness with respect [1] being focused on affordances (*i.e.*, the research questions mention 'affordances' and the model includes an operationalization of affordances), [2] be or include quantitative analysis, and [3] to clearly specify the analysis method and the measurements used.

Tables 1 and 2, below, present the results of our literature review. Namely, Table 1 presents the research design, the analysis, the types of affordances, and the role that affordances had in the respective studies. Table 2 is a continuation of Table 1, in that it presents the roles of the variables in the models developed in the reviewed studies (*e.g.*, predictors, mediators, moderators, or outcomes).

Table 1. Literature review table

Study	Research design	Analyses	Affordances types	Affordances roles
Belitski et al. (2023)	associative	seemingly unrelated regression equations	cultural; human capital; technology;	predictors
Chan et al. (2019)	associative	hierarchical regression	SNS affordances (accessibility, information retrieval, editability, association)	predictors
Chatterjee et al. (2020)	associative	structural equation modeling (CB-SEM)	process management A; organizational memory A; collaborative A;	predictors
C. Chen et al. (2022)	associative	hierarchical regression	affordance-based gratifications (being-there; agency enhancement; community-building; responsiveness; browsing; novelty; activity; play;)	outcomes
X. Chen et al. (2021)	associative	structural equation modeling (VB/PLS-SEM)	utilitarian; hedonic; connective;	predictors
Chris Zhao & Zhu (2014)	associative	structural equation modeling (CB-SEM)	motivational affordances (autonomy; competence; relatedness; leadership; affect)	moderators
D'Ambra et al. (2022)	mixed methods	coding & thematic analysis; VB/PLS-SEM	e-textbook affordance actualization (portability, accessibility, searchability, highlighting, copying, browsing, hedonic value, utilitarian value)	predictors; outcomes
Dubé & McEwen (2017)	quasi-experimental	ANOVA	computer affordances	outcomes
Fengliang & Jianhong (2021)	associative	structural equation modeling (CB-SEM)	live streaming commerce affordances (visibility; metavoicing; guidance shopping)	predictors
Huang & Zhou (2020)	associative	structural equation modeling (VB/PLS-SEM)	social gamification affordances (interactivity; cooperation; competition)	predictors
Irshad (2022)	quasi-experimental	MANOVA	spatial affordances in VR	predictors/moderators
Kim et al. (2022)	associative	path analysis	group play	predictors
Litster et al. (2021)	associative	path analysis	facilitating affordances (helping vs hindering)	mediators
Mao et al. (2023)	associative	multiple regression	social media affordances (presence; persistence)	predictors
Pibernik et al. (2019)	quasi-experimental	ANOVA	time affordances	predictors
Shin & Hwang (2020)	associative	path analysis	technological (traceability; security); emotional (privacy); affective (transparency; trust; satisfaction; reliability)	predictors; outcomes
Stoeckli et al. (2020)	mixed methods	multiple procedures (quant: Q-methodology)	lower- vs. higher-level affordances	outcomes
Suh & Wagner (2017)	associative	structural equation modeling (VB/PLS-SEM)	gamification affordances (rewardability; competition; visbility of achievement; quality of knowledge contribution; quantity of knowledge contribution)	predictors; outcomes
Sundar et al. (2015)	quasi-experimental	multiple procedures (t tests; path analysis)	technological affordances (customization; chatting)	predictors
Sun, Wang, et al. (2020)	associative	structural equation modeling (VB/PLS-SEM)	association; visibility; persistence; editability	predictors
Sun, Liu, et al. (2020)	associative	structural equation modeling (VB/PLS-SEM)	communication visibility (message transparency; network translucence)	predictors
Tsai & Ho (2013)	associative	structural equation modeling (CB-SEM)	affordance-based beliefs (diversity; intuition)	predictors

Study	Research design	Analyses	Affordances types	Affordances roles
Wang & Li (2021)	mixed methods	t tests and coding & thematic analysis	technology affordances (externally scripted vs non-scripted)	predictors
Wong et al. (2020)	mixed methods	t tests and coding & thematic analysis	perceived affordance	predictors
Yu et al. (2023)	associative	structural equation modeling (VB/PLS-SEM)	persuasion-related (cognitive (synchronicity; communication visibility; anonymity; triggered attending); motivational presence (telepresence; social presence; parasocial presence), co-experience (participation; cognitive communion; reasonant contagion)))	predictors
Zhou & Xu (2022)	associative	multi-level SEM, path analysis	annonimity; bandwidth; social presence	predictors

Notes to table: We used the terms 'predictors' and 'outcomes' as substitutes for independent and, respectively, dependent variables (even though it may be argued that the latter is the more natural terminology for the quasi-experimental research), because there were no purely experimental, controlled studies, and to keep a maximum consistency and ease of identification.

Table 2. Literature review table (continuation)

Study	Predictors	Moderators	Mediators	Outcomes
Belitski et al. (2023)	cultural; human capital; technology;			net entry; surival rate (firms); high growth;
Chan et al. (2019)	SNS affordances		criminogenic ooportunities; offending likelihood (inclination to bullying)	SNS bullying
Chatterjee et al. (2020)	harmonious IT affordance (HITA); organizational courage		actualized HITA; exploitative innovation	exploratory innovation
C. Chen et al. (2022)				Instagram use (problematic; habitual;)
X. Chen et al. (2021)	utiltarian A; hedonic A; connective A;		social identity; platform identity;	social commerce engagement
Chris Zhao & Zhu (2014)	motivation (external; introjected; identified; integrated; instrinsic)	affordances; task granularity		participation effort
D'Ambra et al. (2022)	e-textbook affordance actualization	device preferences	e-textbook engagement	e-textbook affordance effect
Dubé & McEwen (2017)	cognitive abilities; computer congiguration			ability to identify computer affordances
Fengliang & Jianhong (2021)			flow experience	impulse purchase intention
Huang & Zhou (2020)	social gamification affordances		psychological outcomes (recognition; social overload)	behavioral outcomes (green IT services use)
Irshad (2022)	spatial VR affordances; time			heart rate
Kim et al. (2022)			reciprocity	bridging social capital; bonding social capital; social status
Litster et al. (2021)	pre-gameplay variables (attitude; knowledge; game use)		helping affordances; hindering affordances	post-gameplay academic (mathematics) performance
Mao et al. (2023)	perceived social media presence; perceived social media persistence;	social tie strength		intention to communicate
Pibernik et al. (2019)	time affordances			perceived usability

Study	Predictors	Moderators	Mediators	Outcomes
Shin & Hwang (2020)	traceability, security, privacy		confirmation; trust; transparency; reliability	satisfaction
Stoeckli et al. (2020)	chatbot themes and constrains			affordances
Suh & Wagner (2017)	rewardability; competition; visibility of achievement		perceived hedonic value	quality of knowledge contribution; quantity of knowledge contribution
Sundar et al. (2015)			sense of control; perceived usability	attitudes toward website
Sun, Wang, et al. (2020)	ESMP affordances		knowledge acquisition; knowledge provision	creative performance
Sun, Liu, et al. (2020)	communication visibility		perceived social value; perceived information value; perceived hedonic value	excessive ESM use at work
Tsai & Ho (2013)	affordance-based beliefs; IDT-based beliefs		TAM-based beliefs (perceived usefulness; perceived ease of use;	attitudes towards smartphone usage)
Wang & Li (2021)	technology affordances (externally scripted vs non-scripted); others			role emergence
Wong et al. (2020)				level of expectation
Yu et al. (2023)			political mindfulness	political engagement intention
Zhou & Xu (2022)				dialogic communication measures (mutuality, pro-pinquity, empathy, risk, commitment)

5. DISCUSSION AND CONCLUSION

5.1 Summary of the Findings and Contribution to the State-of-the-Art

In summary, we identified that most of the studies focusing on affordances had an associative design (N = 18, *i.e.*, 69%), followed by an equal number of quasi-experimental and mixed methods studies (N = 4, 15%), with a note that two of the mixed methods studies also included associative designs. With respect to the roles that the affordances played in the studies' models, these were predominantly predictors (N = 17, *i.e.*, 65%). Studies that used affordances as outcomes or as outcomes and predictors, concomitantly, followed in equal proportion (12%, N = 3). Finally, there was only one of each study that used affordances as mediators or moderators.

We caution against interpreting these results as evidence that there are only very few studies that used quasi-experimental designs or performed various experimental manipulations. Quite to the contrary, that is not true at all, as a huge number of studies (not included here because they didn't meet the criteria for thorough reporting of the measurements or for not using scales for operationalizing the constructs) did, indeed, use quasi-experimental designs. However, as uncovered during our selection process, the problem was that most studies did not have a thorough reporting procedure and/or a rigorous description of their measurements (*e.g.*, lacking important information regarding the validity and reliability).

If anything, supported by our data, we want to drive home the idea that the field could use more experimental or quasi-experimental designs that go beyond case studies and in-house designed measurements. To that effect, the first significant conclusion that we derived from our literature review is that the number of complete reports, compared to the number of studies published on the subject is overwhelmingly low. Second, we noticed that many studies entertain a tendency to use 'affordances' as an umbrella term, covering or overlapping with, what are, in fact, 'system' or 'device' functionalities. This overlap, in itself, is understandable and perhaps unavoidable, but it becomes worrisome when is doubled by shortcomings of the theoretical

underpinnings that should guide the operationalization of those affordances. Third, the number of quantitative primary studies, regardless of the thoroughness of their reporting, is significantly smaller than that of qualitative studies. This aspect, again, is not unusual, as many studies report on niche projects and many researchers are under pressure to publish quickly.

Nevertheless, qualitative research and case studies are notoriously difficult to reproduce and, often, it is not even desirable or relevant to do so. Rather differently, quantitative research not only requires thorough reporting of the methodology (and the measurements used) but actually invites replications. Furthermore, it is very often the case that many quantitative studies use the same measurements, exactly because they showed good psychometric properties in previous studies. In that regard, we must acknowledge that the literature does include notable instances of excellent qualitative studies, and the number of thorough qualitative research appears to be increasing (see, for example, the qualitative studies of McCarthy et al., 2022; or Lainema et al., 2023 among others).

5.2 Limitations and Future Directions

Our study must acknowledge a series of clear limitations. First, no literature review can assert absolute confidence in identifying all relevant publications, except, perhaps, when the initial pool of studies is very small, to begin with. A large number of starting publications leads directly to increased risks of unintentionally omitting relevant studies. Second, the writing styles and manuscript structures vary greatly and directly reflect the diversity of contributing fields. Specifically, researchers from various fields observe different styles of writing and journals in various disciplines often have quite different requirements for structuring the manuscript and standards pertaining to reporting. This makes it very difficult to pinpoint and extract exact information using regex-based separation of text sections. Moreover, regex-based information extraction, as natural as it may be, is also prone to errors of omission, when synonyms or paraphrasing is used instead of 'classical' or traditionally coined expressions, headings, and phrases.

In future refinements, we plan to use machine learning to train a model capable of identifying the sections of text of interest, based on semantic similarity. Furthermore, we plan to continue this analysis by performing topic modelling, such as, for example, based on Latent Dirichlet Allocation (LDA), to get more insight into the similarities and dissimilarities of the studies of affordances. As can be seen from the reporting of the selection process, the majority of studies identified during the initial stages of our literature search used a qualitative design and/or were case studies. Manually going through each of these would be a daunting and ultimately, unrealistic task. However, a machine learning approach would address a second avenue of interest to us, i.e., uncovering the conceptualisation of affordances and their roles in qualitative studies, as well. Lastly, we must note that it seems, at times, that there is a 'real and present danger' that pretty much everything under the sun can potentially be construed in terms of affordances, and we wholeheartedly align with the existing calls for a rigorous approach to operationalizing affordances (J. Davis & Chouinard, 2017).

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