Researching Inhabitant Agency in Interactive Architecture

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ABSTRACT

The study of Interactive Architecture (IA) spans over several decades and appears to be gaining increasing momentum in recent years. Yet, inhabitant-centered approaches towards research and design in the field still have a long way ahead to explore. Particularly, we observed that the examination of IA's social relevance in literature is still incipient and ill supported by evidence. The study discussed in this paper is attempting to remediate this gap by exploring one of the first socio-political arguments around the relevance of IA, namely inhabitant empowerment and agency. It investigates whether an inhabitant's relation and experience with interactive spaces, conceived according to different interaction strategies, increases the participants' perception of their own agency in the space. In this paper, we briefly explain the prototyping of an interactive space-plan designed to emulate the behavior of four basic models of interaction. Finally, the paper presents an experimental study set to test inhabitant agency in IA. It concludes that IA has the potential to increase inhabitant agency, but that this is very dependable on the system's design regarding behavior and interaction.

1 Interactive space-plan prototype.

INTRODUCTION: A SOLUTION LOOKING FOR A PROBLEM

Interactive Architecture (IA) can be broadly defined as an architectural setting computationally enabled to sense its environment and respond accordingly in a dynamic feedback system. It is still a field that relates more closely to science fiction than to the mainstream production of architecture. Yet its study spans over several decades and has gained substantial momentum in the last few years, possibly due to the increasing availability of inexpensive and easy-to-use electronic components.

In a previous study (Costa Maia and Meyboom 2015), it was argued that most recent investigations in the field are centered on technological availability, with ad hoc discussion regarding its context in the built environment. Little research exists to date that tries to identify whether IA can be an adequate solution for real-world problems and demands, specially regarding inhabitants' needs. In fact, very little research has been done on inhabitant experience of interactive spaces in general, hindering our ability to justify its use or to properly ground design decisions.

The literature on IA abounds with arguments regarding the social relevance of data-driven adaptable environments (Costa Maia and Meyboom 2015). Each of the several rationales for IA presented in literature require further scrutiny. They address important topics, but they do not empirically demonstrate that IA is an adequate response for them.

This research begins the task of investigating IA's possibility of fulfilling one of its many untested claims. We explore one of the main assumptions which we deem highly pertinent to the domain of IA: inhabitant empowerment and agency. Its selection among others is justified by: 1) its critical participation in early debates in the field, 2) its conceptual relation with fundamental notions of IA, 3) a recent upsurge of interest on (architectural) production democratization, and 4) a personal interest on the political implications of the topic.

IA's initial relation with the problem of inhabitant agency is explained, to large extent, by its foundation in cybernetics. Gordon Pask, a main proponent of the second generation of cyberneticians, introduced the relevance of feedback, systems design, and underspecification in architecture. Through systems thinking, IA would allow for buildings to become components of empowering environments by integrating the human user as part of a larger control loop.

Pask explicitly claimed that, in IA, "the designer is no longer conceived as the authoritative controller of the final product;" instead, "an environment should allow users to take a bottom up role in configuring their surroundings in a malleable way." Haque (2007) also argued that applying Pask's ideas to architecture "is about designing tools that people themselves may use to construct — in the widest sense of the word — their environments and as a result build their own sense of agency." Authors such as Negroponte (1975) have also extensively framed IA, or computing enabled environments, as primarily concerned with freeing the user from the paternalistic figure of the architect by instead providing agency and responsiveness.

More broadly, interactivity has often been intrinsically associated with the idea of user empowerment. Andrejevic (2009) explains that early advocacy for interactivity in media studies sought to subvert traditional structures that helped reproduce power and social relations.

The extensive discussion around participatory design in architecture since the 1960s proves that this question of who should control the formation of the built environment is an important concern of architecture. Instead of focusing on anticipatory demands, exploring inhabitant agency and empowerment in IA may help address immediate challenges faced by designers.

As already argued, there is a very scant number of studies generated by the IA community which address specific current demands in architecture and which generate evidence regarding the adequacy of specific strategies towards specific problems. Academic work to provide support for decision-making in the design of such systems will become increasingly relevant and potentially determinant on the success of following projects. The lack of such supporting information might be a key reason why IA is largely still limited to speculative manifestations, even several decades after the concept was popularized.

This research is therefore framed to provide an understanding of IA with regard to one specific relevant problem, and in testing the adequacy of IA as a solution for that problem. Only through proper scrutiny and data support may we begin to understand the relevance of IA towards inhabitant agency, or any other rationale of interest.

This paper presents a study of how different models of interaction might influence inhabitants' perception of agency and related concepts. It describes the process of prototyping interaction models and conducting a user experience study on four different forms of system behaviour and user interaction.

WHAT IS INHABITANT AGENCY?

The topic of agency is not a simple one and there is much to say in relation to the subject and its study in social sciences and other fields. However, in the context of this research, a few concepts will be highlighted. Firstly, in its most fundamental meaning, agency can be broadly defined as the capacity of an actor to act on the world. It is also important to clarify the distinction between the ideas of inhabitant agency and architectural agency in IA. In architectural agency it is the architecture itself which must have internal goals and be able to act in their pursuit, and these goals may or may not be aligned with goals of the inhabitants. In such instances, IA is typically approached as intelligent and/or autonomous machines. Several authors have directly or indirectly discussed an idea of agency in IA that refers to architectural agency primarily (Calderon 2009; Adi and Roberts 2010; Jaskiewicz 2013). In this research, however, we focus on inhabitant agency—that is, on how the environment enables people to accomplish goals of their interest.

This research adopts the concept of human agency as it is proposed by the Capability theory and most centrally to the work of the Nobel prize-winning economist Amartya Sen. Sen's definition of "human agency" stands for people's freedom to act in pursuit of whatever goals or values they regard as important (Alkire 2005). It allows them a "systematic ability to achieve high levels of functioning (which may or may not be realised in practice)" (Johnstone 2007). Systematic is the key word in this definition because, contrary to allowing a person accidental access to wellbeing, it ensures that wellbeing may be sustainable and robust across time and context (Johnstone 2007).

Therefore, this research is interested in the social sciences' use of the term agency, which transcends a subject's basic capability of action on the world and studies it with regard to the socio-political structures in which it is inserted. How might an IA apparatus provide the spatial/environmental support to improve an inhabitant's agency with regard to the processes that shape his/her built environment? This kind of argument questions the architect's often paternalist role in designing environments and spatial configurations deemed best for the inhabitant. It also draws an immediate connection with IA, in IA's ability to offer inhabitants a sustained say in the shaping of space, thus potentially allowing systematic access to environmental wellbeing.

In order to assess agency in inhabitants' experiences, this research used measures of empowerment, autonomy (from self-determination theory) and capability (from self-efficacy theory) as proxies for human agency (Alkire 2005).

HOW CAN WE TEST INTERACTIVE ARCHITECTURE?

This paper briefly discussed how interaction could potentially be an instrument to bring about inhabitant agency within architecture. To validate these types of claims, we need to be able to empirically test the interaction aspect of IA concepts. After all, it is its interaction component which qualifies IA differently than other, better-known instances of architecture. This work based itself in well-tested methods from the fields of user-centered design and interaction design, creating a "microcosm" that could be used to test ideas out and to evaluate specific user experiences of interest, such as that of human agency.

The mental model is a central concept to the field of human-computer interaction (HCI). Upon exposure to a system, users can develop a mental model of that system; that is, a conceptual understanding of what the system is and how it works. Mental models were also important concepts in early discussions around IA (e.g. Negroponte 1975; Wellesley-Miller 1975), as they were very relevant to the artificial intelligence debates of the time. When addressing IA as intelligent participants in a conversation that manifests understanding, users will have not only a mental model of the building, but also a mental model of themselves, and a mental model of the building's model of themselves. All of these are important factors influencing the interaction.

Considerations of mental models in the context of IA raises some challenges. The first one is that people typically already have strong mental models of what buildings are and how they behave. Also, given the fact that the built environment is composed of different juxtaposed layers, which extend themselves in a continual fabric, it might be difficult for users to build unified mental models for IA—or for an ecosystem of IAs. Scholtz and Consolvo (2004) point out a similar question regarding Ubiquitous Computing. They ask: "how do users know when they are in a smart room, and how will they know how to interact with such a room?" In fact, IA can easily go from empowering to oppressive if inhabitants of the space cannot understand the system.

Given these difficulties, we propose that metaphors provide a useful way to study different forms of IA interaction, especially with regard to empowerment. The issue of metaphors is directly related to that of mental models. Metaphors are intended to encapsulate an understanding of how a system is expected to work a priori, as part of a deliberate design effort. That is, they seek to start with the desired mental model users should formulate—one that is familiar and pertinent to the problem domain—and allow designers to conceptualize a system design based on that information, not the other way around.

In general, we observed that the descriptions and analysis of interaction that can be found in IA publications may be roughly classified in three groups of metaphors. The groups are hardly isolated categories, but rather sequent marks in a continuum.

The first group of authors assume that IA will not only have human-like intelligence, it will interact as such (e.g. Adi and Roberts 2010; Achten 2013) by following a metaphor of human-human interaction (see Waugh and Taylor 1995). Interaction happens via natural speech as well as deictic and representational gestures, following the “put-that-there” paradigm, and possibly extending to cover the whole breadth of human communication forms. Only with human-like intelligence and an ability to maintain a dialogue with users can a truly interactive architecture be achieved within this paradigm. This group of authors explicitly focus on concerns of intelligence (mostly around cybernetic concepts) and speculate on its implications.

The second group of authors is by far the most numerous (e.g. Fox and Kemp 2009; Cetkovic 2012), although its approach to IA seems to avoid the discussion of interaction in detail. They are the group that a “black box” critique most suitably fits. In these cases, IA is the perfect machine that can identify needs when these needs are reasonably identifiable, provide logical spatial support to activities it understands, and allocate/manage spatial and functional resources in ways to better support specific goals. The machine is efficient and invisible, and the inhabitant wants to be disburdened of as many tasks as possible.

Authors like Jaskiewicz (2008) argue that achieving such goals will only be possible if IA has an ability to reason and learn, although it can also be argued that other means exist (e.g. Gajos et al. 2002). However, the biggest difference between the first and the second groups is that of approach, each comprising very different behavior/interaction metaphors. In one case, IA behaves and communicates as a human agent. In the other case, the agent ethos is transparent, with communication being mostly limited to context interpretation and adequate physical response.

The third group of authors, perhaps of smallest representation, describe the emergent behavior of distributed intelligence and/or the organic-like constant adaptation of a building to the ecosystem it is inserted in (e.g. Fox 2009). Interaction with inhabitants is undefined, possibly occurring in different ways, and it is non-deliberate. This kind of IA is perhaps the one that most closely approximates the natural environment around us.

In the interest of studying inhabitant agency, and after reviewing the literature on empowerment in human-computer interaction (see Weller and Hartson 1993), one more type of behavior was also included in this research. This fourth group can be described as one where inhabitants are given the ability to directly control a space’s outcome, and where contextual data is used to assist inhabitants in their decision-making instead of making decisions for them.

Not a single publication was found by the authors in the field of IA describing such a system, and it can be argued that fully controllable systems would fail to fulfill the most basic definitions of IA. However, it is possible to conceive of systems where inhabitants simply assume more roles in the feedback control loops, conceptually sustaining the pertinence of this form of interaction and system behavior.

Sterk, for instance, discusses the concept of dynamic stability (2006), which can also be referred to as shared or assisted control. It defines systems that allow inhabitants to focus on symbolic actions of control, while leaving the system to provide solutions for lower level components of that action. Yona Friedman also describes assistive systems that provide inhabitants with feedback on the consequence of their design decisions (information), although all the decisions are still the inhabitants’ to take (Negroponte 1975).

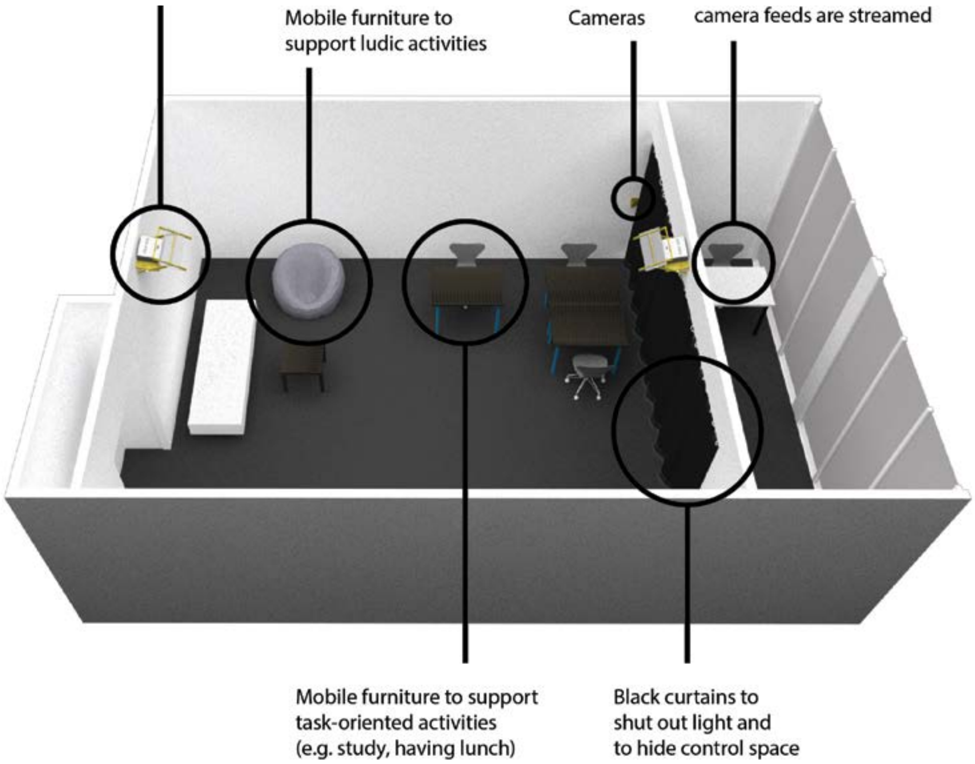
These four groups defined the basis for four interaction models/metaphors that this research prototyped and tested. Testing inhabitant agency considering only one approach to interaction would greatly limit our ability to assess IA more integrally in relation to its claims. Instead, by testing a set of popular but different approaches to interaction, we can achieve results that are more meaningful and generalizable. Respectively, we refer to the four models developed as: human-like intelligence model, self-adjustment interaction model, emergent behavior interaction model, and direct manipulation interaction model.

HOW WAS INTERACTION PROTOTYPED?

Overview

An interactive space was assembled in a classroom in the School of Architecture and Landscape Architecture at UBC. It was conceived as an interactive space-plan (i.e. only one of Brand’s [1995] building layers), where internal partitions could transform according to inhabitants’ input. In order to allow for unrestricted arrangements of the space-plan, the internal partitions were proposed in a mixed reality environment: the internal walls and partitions are virtual, and projectors were used to create visual representations of these partitions directly onto the real world. The complete design process has been described in Costa Maia (2016). Figure 2 illustrates the physical setup, including the location of the two short throw projectors.

The behavior of virtual internal partitions was the focus of this project, and their prototyping was crucial for testing IA in an



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2 Model illustrating physical set-up of the interactive space-plan in mixed reality.

3 Example of an inhabitant interacting with the space-plan via the direct manipulation interaction model.

experimental setup. The main technique used for the interaction prototypes in three of the four experiments is one known in Interaction Design as Wizard of OZ, which consists of an operator effectively controlling the behavior of the space without the knowledge of inhabitants. This methodology allows seamless interaction between the 'room' and inhabitants without the necessity to program the room's intelligence. This is important as any technical problems with the behavior would affect people's response to the experiment and their perception of agency. An application was developed in JavaScript that allowed for the easy creation and modification of the representation graphics in these cases. The final interaction model operation, on the other hand, was completely automated (described further on).

The following subsections describe the behavior of each interaction model as it was developed and employed in the interactive space prototype.

Direct manipulation interaction model

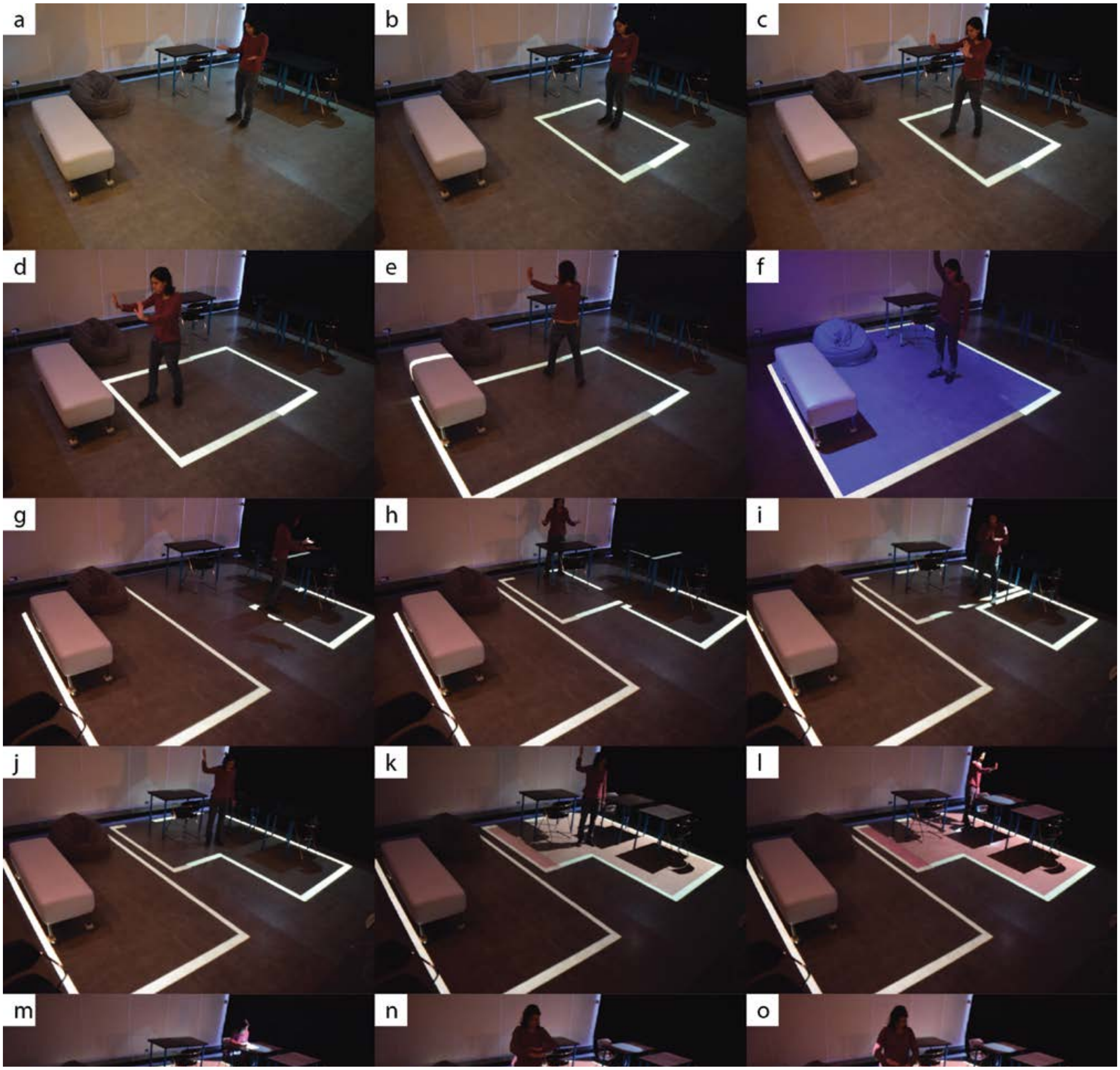
Users control final disposition through gestures and by directly interacting with boundaries. The computer checks if output is coherent and gives informational feedback on problematic dispositions, e.g. lack of access. Users can directly 'push' any boundary to make it move, create or delete spaces, merge adjacent spaces, create spotlights, or control color and lighting. A total of eight intuitive gestures must be learned. This way, users can easily redraw the spaces according to need, and they have an ample power to define the final internal partition of a building. Figure 3 illustrates in a set of frames how an inhabitant can directly modify the virtual partitions and spaces using the inputs supported by this interaction model.

Human-like communication and intelligence model

Similar functioning as the previous condition. However, users do not manipulate the system directly and they do not need to remember any of the command gestures. Instead, an intelligent entity controls the system. The intelligent entity can learn about users and might not need instructions or requests for many of the procedures. Otherwise, the intelligent entity communicates with users using natural language and high-level symbolism. Participants can talk to the room to request any changes they may want or to socially engage with the room. The room may also engage with inhabitants proactively, according to its own goals and its personality. Figure 4 illustrates a verbal dialog between the inhabitant and the intelligent room with a purpose of modifying the space.

Self-adjustment interaction model

This model offers fewer possibilities for users to directly control the output. A standard, base phenotype exists and is adapted depending on use patterns, in a context-aware manner. That is, as users engage in activities, the system recognizes each context



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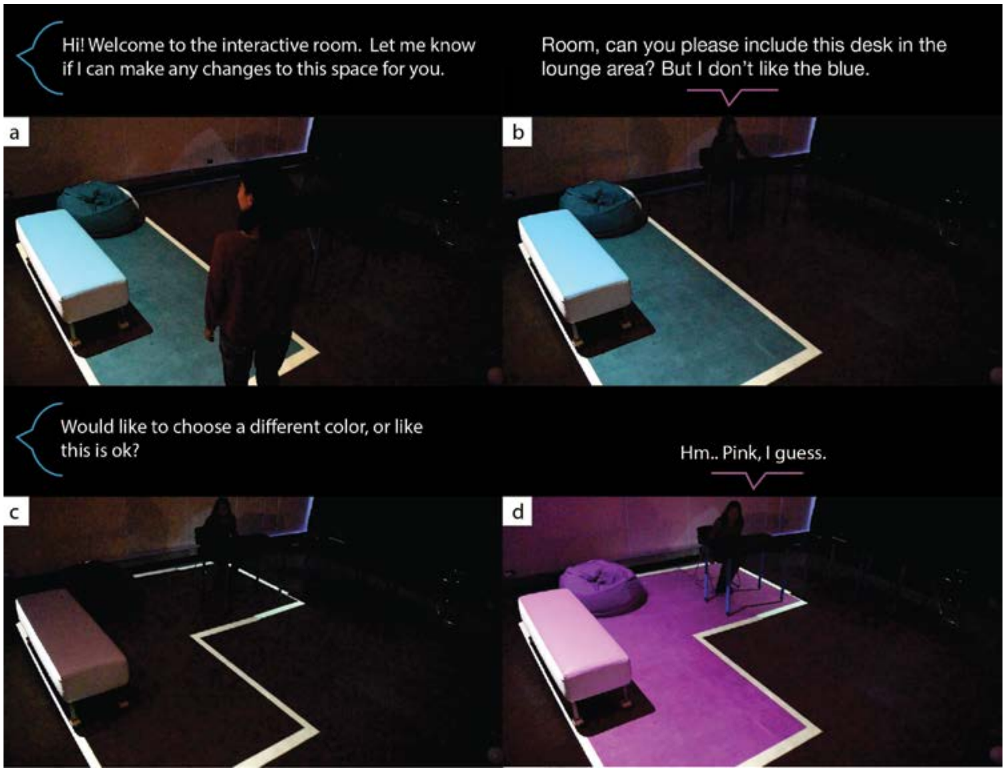
and provides the adequate enclosure layout, as well as adequate lighting levels, for that specific activity and context. Adequate layout for any activity is pre-established (although evolving) but parametric, so it is responsive to a set of parameters (such as number of people participating). The logic of the system is primarily concerned with functional arrangement depending on activities taking place. The output is always based on the drawing of the perimeter with confined properties. Users can only give correctional feedback. Thus, this interaction strategy follows the following logic flow: (1) to identify which activity is taking place, (2) to identify contextual parameters for that activity, such as number of people involved, (3) to define adequate area, lighting, and color based on activity and parameters, (4) to constantly check for changes in activity and parameters, adapting accordingly, (5) to constantly check whether the last change performed received correctional feedback, and (6) if correction is flagged, undo changes, record learning data, and re-run logic flow. Any change in the room always follows these steps (see figure 5).

Emergent behavior interaction model

The different bounded spaces interact and respond to each other in a constantly evolving configuration. Users' actions in the room



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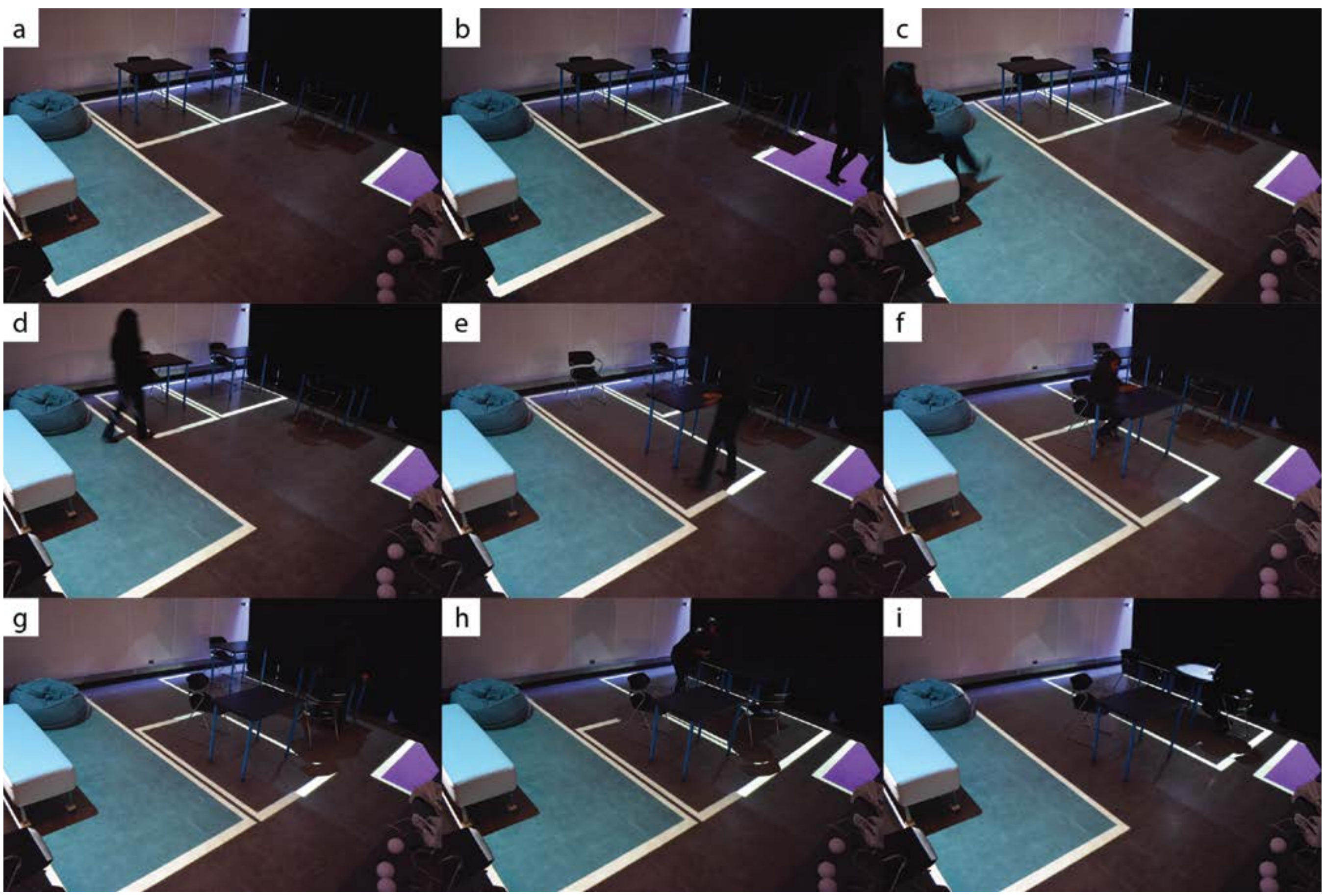

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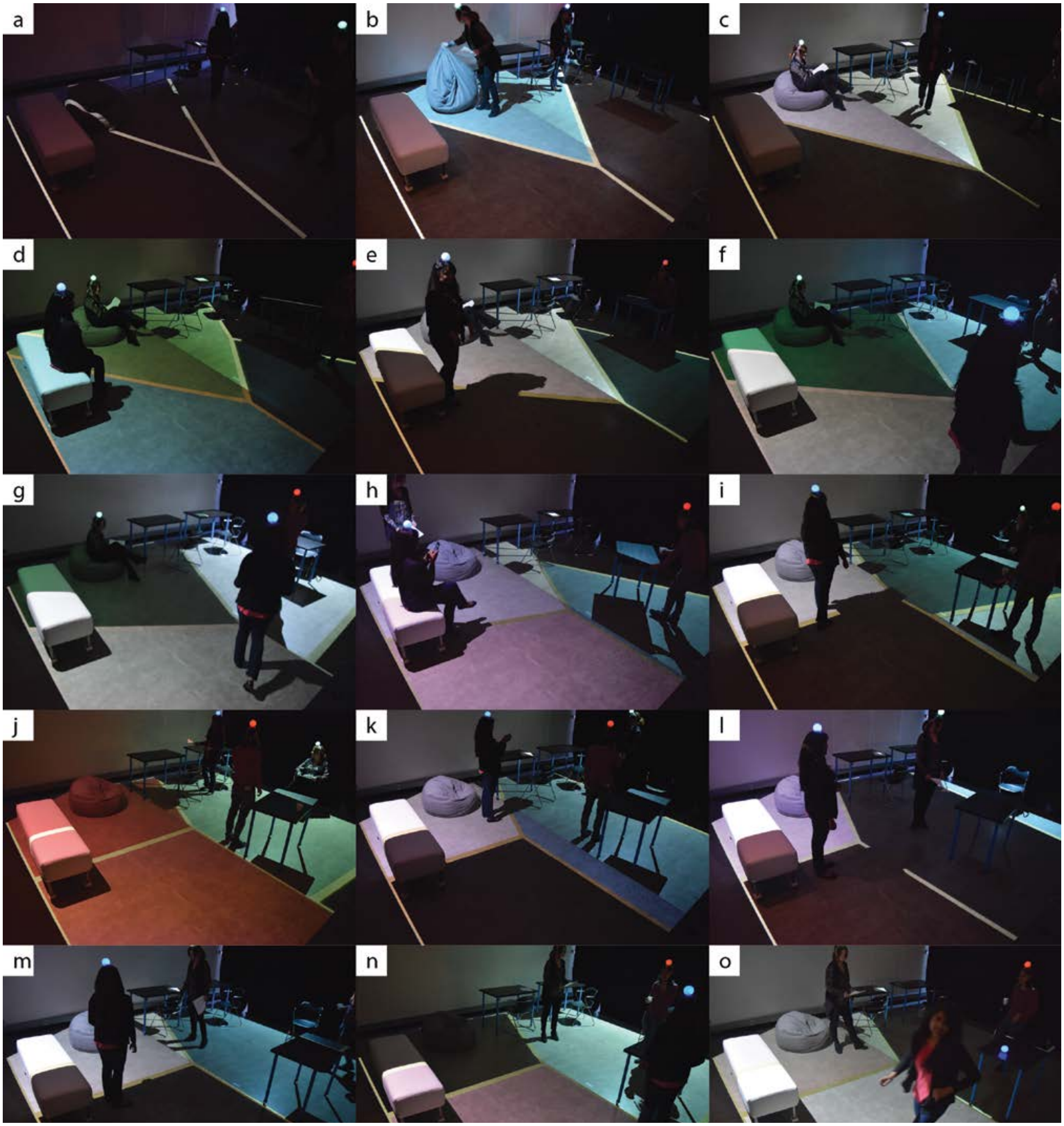
4 Example of an inhabitant interacting with the space-plan via the human-like intelligence interaction model.

5 Example of an inhabitant interacting with the space-plan via the self-adjustment interaction model.

6 Example of an inhabitant interacting with the space-plan via the emergent behavior interaction model.



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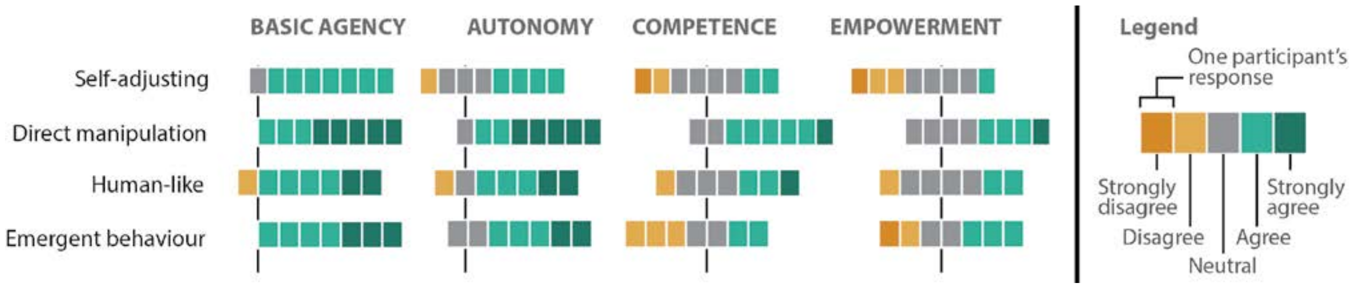
influence the way the space evolves by causing local changes and disturbances that may propagate and influence the system at a larger scale. The rules of the system's behavior, however, do not refer to functions or spatial fitness, nor do they have a higher order goal governing to whole. Instead, the whole is simply the emergent result of smaller, local interactions. The ways participants may influence the evolution of the room are: crossing of boundaries, persistent occupation, amount of movement inside a bounded space, entering or leaving the room.

Because of the complexity of the emergent behavior, this model did not use the Wizard of Oz method. The entirety of the behavior was executed by a computer program custom written in Python, with a tracking system using glowing markers, cameras



7 Comparison of measures of basic agency, autonomy, competence and empowerment: summary diagram.

and the OpenCV library. Figure 6 illustrates the room's behavior, showing frames taken 5 minutes apart.

HOW DID WE TEST AGENCY IN IA?

After the interactive space was assembled, participants were invited to occupy it. The study ran for four days, and in each day the space emulated one of the interaction models.

Participants filled questionnaires after participating in the study. The questionnaire asked participants about their experience of the space (using established UX survey material), plus specific questions designed to inquire about participants' perception of personal agency towards the space (based on self-efficacy and self-determination theories). Self-reported perceptions of autonomy, empowerment, and competence were measured as instrumental proxies for agency. Related concepts, such as perception of control, ownership, authorship, and attachment were also measured in the survey.

Additionally, participants were observed during their use of the space. Aspects such as whether participants chose to use the system features, and the situations when they chose to do so, were recorded in written form. Thirty participants completed all the stages of this study.

DID IA RESULT IN INHABITANTS EXPERIENCING INCREASING AGENCY?

The main results of the study are summarized in graphical form in Figure 7, which shows the variation of different indicators on simple agency, autonomy, empowerment, and competence for each interaction model. Extensive analysis can be found in Costa Maia (2016).

All models show a significant perceived increase in agency and it is clear that the indicators vary considerably depending on the model of interaction. The self-adjusting model has the lowest levels in all measures of agency, whereas direct manipulation had the highest. Statistical analysis of the results, however, does not bear out a significant relation between the higher levels of inhabitant agency experienced and aspects such as perception of control, autonomy, attachment, authorship, and ownership. On the other hand, when jointly analyzing the models that allow for direct input (Direct Manipulation + Human-like Intelligence interaction models) and indirect input (Self-Adjusting + Emergent Behaviour interaction models), the results show that there is a statistically significant difference between the groups, suggesting that in order to promote human agency IA must allow inhabitants direct input on the interaction outcome.

CONCLUSION

This study supports the plausibility of Negroponte and others' thesis that inhabitant agency can be produced by IA. In taking this first step, we can start to rely on evidence to support the different claims that have been put forward regarding the social relevance of Interactive Architecture. The testing and analysis methodology put forward by this paper is intended to be a prototype for future experiments on the efficacy and relevance of IA. Despite the fact that further studies are necessary to provide more robust and statistically defensible evidence, this exploratory research is an important step forward.

This study also presents a way to study IA through different models of interaction. The results show how experiences such as agency can vary significantly according to different forms of interaction and behavior. It suggests that interaction models have a significant impact on inhabitants' perceptions of agency and empowerment. As such, careful attention should be paid to the models of interaction that are adopted and it is likely that the most effective interaction model may vary depending on the design intent of the interactive architecture being developed.

LIMITATIONS AND FUTURE RESEARCH

The short periods of time that participants spent inside the interactive room, alongside the high density of interaction (average of one interaction every 1.28 minutes), portrays a pattern that suggests that most participants came to the interactive room to explore the space as a primary intent. This observation defines a significant limitation of this study. Future studies must consider surveying the use of interactive spaces on a daily basis for an extended period of time, allowing inhabitants to interact with the architecture and IA systems more thoroughly and habitually, for beyond the effect of novelty. Future research should also test interaction metaphors and options within those metaphors more thoroughly, as different design decisions are possible inside each metaphor.

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IMAGE CREDITS

Figures 1, 3–6: Nair, 2016

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