Evaluating HCI Design with Interaction Modeling and Mockups
A Case Study

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Abstract: Interactive systems are increasingly present in daily life, but many people still face difficulties to use them. We believe that using models and artifacts to represent the interaction in a systematic way during systems design may prevent such difficulties. In this paper, we investigate the combined use of MoLIC, an interaction modeling language, with user interface mockups. While both artifacts are supposed to promote the understanding of user goals and the designer's reflection on alternative solutions and decisions regarding the interaction, we have not found evidence of their usage impacts on quality. Thus, this paper presents an experimental study on the joint usage of MoLIC interaction diagrams and mockups during systems design, aiming both to identify participants' perceptions on the joint use of the two artifacts and to analyze the quality of the generated artifacts by observing which types of defects would occur. The results show that, although some participants found that MoLIC diagrams were not very easy to build, most participants considered the creation of mockups based on MoLIC diagrams useful. In addition, the number of defects found in the MoLIC diagrams points to the need of developing techniques to evaluate the artifact before proceeding with the design process.

1 INTRODUCTION

The software industry is interested in offering users high-quality interactive experiences, so users will not have problems with interactive systems. To Puerta (1997), one way to reduce problems is by employing an interaction model during system development, because it describes the behavior of both user and system during the interaction, thus allowing the detection of problems early in the design process.

Paula et al. (2003) devised the MoLIC language (Modeling Language for Interaction as Conversation) as an epistemic tool to support interaction design. MoLIC is grounded in Semiotic Engineering (De Souza, 2005), a theory of HCI with particular focus on communication between the designer[1] and the user mediated by interactive systems. MoLIC diagrams represent the interaction as a metaphor of the conversations that may occur between the user and the user interface, and therefore all possible ways of interaction, including alternative ways to achieve the same goal (Paula et al., 2003).

Sangiorgi and Barbosa (2009) proposed an extension of MoLIC to include mockups, which are sketches of screens to represent the user interface before the actual development of prototypes. By doing so, the designer can have an overview of the application at the level of behavior and of the low-fidelity appearance of its user interface. To evaluate their proposal, they conducted a case study on the combined use of MoLIC diagrams and mockups during the design of applications. One of the case study results showed that the interaction and the user interface cannot be considered fully independent of each other. Therefore, the combined use of MoLIC and mockups promotes a deeper reflection by the designer on the interaction. However, research on the impact of using this approach over the quality of the resulting interaction design was not found, which brings some questions to mind: What types of defects can be found in the generated artifacts? How

[1] We use the term *designer* for the Software Designer, also called Information Architect, i.e., the professional involved in designing the interactive solution.

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do the designers view the combined use of the artifacts? Is there an ideal sequence for constructing the artifacts?

In this paper, we report a study that analyzed the impact on quality of two variations of combined usage of MoLIC interaction diagrams and mockups during interaction design: MoLIC-first or mockups-first. We investigated the participants' perceived ease of use and usefulness of each approach, as well as some more general opinions. We also analyzed the quality of the interaction models and mockups created by the participants, by identifying defects in the generated artifacts.

The next sections present concepts about interaction design with MoLIC diagrams and mockups. Section 3 describes the planning and execution of the experimental study. In section 4 we report the quantitative and qualitative analyses of the study. Finally, we present some concluding remarks and discuss envisioned future work.

2 INTERACTION DESIGN

Interaction design aims to support people in their activities using these interactive systems. According to Semiotic Engineering, the user interface is the *designer's deputy*, i.e., it represents the designer at interaction time, enabling the mediated designer-to-user metacommunication about the designer's view, her design decisions, and how the user can or should interact with the system to achieve his goals (de Souza, 2005). When the user interacts with the system through the interface, he interprets the metacommunication message and responds to it to achieve his goals. MoLIC was created to represent the metacommunication message, allowing the designer to reflect on his/her interaction design solution.

During interaction design, the designer must attempt to anticipate communication breakdowns and design ways for the user either to avoid breakdowns or to restore the communication after them, so that he can continue using the system to achieve his goals (Paula et al., 2003).

2.1 Modeling Language for Interaction as Conversation

MoLIC allows us to represent in diagrams an application's apparent behavior, in the sense of how the designer communicates it and how users experience it (Sangiorgi and Barbosa, 2009). MoLIC diagrams represent the interaction as a conversation between the user and the designer's deputy, without detailing the user interface, and allowing designers to reflect on the interaction alternatives they may provide to the users (Paula et al., 2003).

To illustrate the MoLIC diagrammatic notation, Figure 1 represents a hypothetical system for hotel search, including the basic elements of MoLIC diagram, according to Sangiorgi and Barbosa (2009):

a) Scene: a rounded rectangle depicting the moment in the interaction when it is up to the user to decide how the conversation should proceed. The first compartment contains the topic of the scene and represents the user goal when interacting with the designer's deputy at that particular moment. The second compartment details the scene, as described below:

- **i. Signs:** represent the information involved in the user and deputy utterances. For instance, in the *View all hotels* scene, we have the signs: "name, description, rating and price."
- **ii. Utterances:** make up the dialogue and specify who is sending the sign, the user (u:), the designer's deputy (d:, used for system output), or both (d+u:, for user input). In the *View all hotels* scene, we have signs uttered by the designer's deputy alone (e.g. "d: name, d: description, d: price") and signs uttered by both the designer's deputy and the user (e.g. "d+u: rating").
- **iii. Dialogues:** represent a fragment of the conversation about a topic, and is composed by utterances, e.g. "view hotels, view hotels list, search".
- **iv. Dialogue Structures:** dialogues can be composed of other dialogues, according to some structure represented by the reserved words SEQ, XOR, OR or AND. In Figure 1, the dialogue "search hotel" is composed of dialogues structured with AND, to indicate that they are all necessary, but they can occur in any order.

b) User Utterance: a directed line labeled with "u: content," e.g "u: search hotel", depicting the user's intent to proceed with the conversation in a given direction.

c) System Process: a black box depicting the internal processing of a user request. It is used only when it is necessary to provide feedback to the user, otherwise the user will not know what has happened.

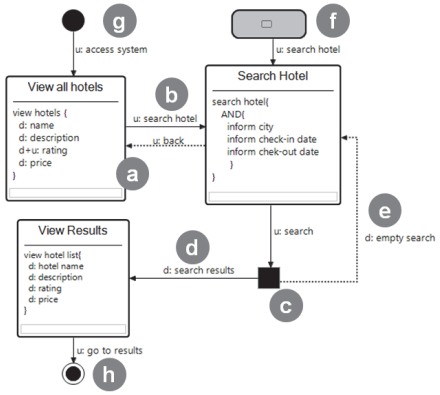

Figure 1: A basic MoLIC diagram.

d) Designer Utterance: a directed line labeled with "d: content" (e.g. "d: search results"), depicting a designer's answer to a user request, typically given after a system process.

e) Breakdown Recovery Utterance: a dashed directed line, depicting an utterance to help the user recover from a communication breakdown or to allow him to change his mind regarding his goal. It may be uttered by the designer or by the user, e.g. "u: back" or "d: empty search"

f) Ubiquitous Access: a gray rounded rectangle depicting the opportunity for the user to change the topic of the conversation at any time, to achieve a goal different from the current one.

g) Opening Point: a filled black circle indicating where the interaction can start when the user accesses the system.

h) Closing Point: a black circle within a larger white circle, representing the end of the interaction, i.e., when the user leaves the system.

After defining the structure of the conversation, we obtain a global view of the interaction between the user and the designer's deputy.

2.2 From the Interaction to the User Interface

After the total or partial definition of the interaction, the designer starts to design the user interface, usually through mockups, which are sketches of the user interface that reflect the needs of the customers in more concrete terms of presentation (Luna et al., 2010). Mockups allow representing the components of the interface and the navigation across different presentation units ("screens") of an application.

Barbosa and Silva (2010) present some common decisions regarding interface design, based on the elements in a MoLIC interaction diagram. We next instantiate some decisions made for the interface design of our hypothetical system, as illustrated in Figure 2.

a) Scene: mapped onto (parts of) presentation units, such as screens, windows or pages (e.g. search hotel scene → "Search" page and view results scene → "View Results" page).

b) User Transition Utterances: mapped onto buttons or links (e.g. utterance "u: search hotel" → "Search" button).

c) Breakdown Recovery Utterance: Also mapped onto links and buttons at the interface, so that the user can change the course of the conversation (e.g. "u: back" → "Search" link).

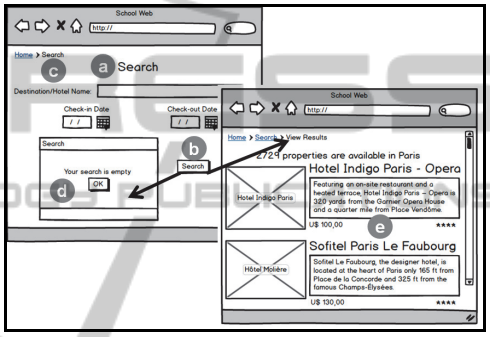

Figure 2: Interaction diagram mapping modeled with MoLIC for interface design.

d) Designer's Deputy Utterance: mapped on the user interface as status and error messages, and may also change the course of the conversation (e.g. "d: empty search" → feedback about the data not having been found; and "d: search results" → list of search results).

e) Signs: mapped onto text, images, and input fields (e.g. "hotel name, description, rating and price" → hotels information in the search results).

During both the construction of MoLIC diagrams and the mapping of the interaction diagram onto mockups, defects can be included from any misunderstanding or mistransformation of information, as occurs in other stages of interactive systems development. To investigate the types of defects that can be found in these artifacts and thus contribute to their quality in interaction systems design, we conducted a case study, described next.

3 CASE STUDY

We analyzed two design approaches based on the

joint use of MoLIC diagrams and mockups: (1) elaborating mockups based on the MoLIC diagram of an interaction scenario; and (2) creating the MoLIC diagram based on mockups. The study also aimed to obtain evidence about the benefits and drawbacks of these two interaction design approaches. This section describes the study planning and implementation.

3.1 Case Study Planning

We defined the goal of the study according to the Goal-Question-Method (GQM) paradigm (Basili and Rombach, 1988), as shown in Table 1.

Table 1: Experimental study goal.

Analyze	Design approaches based on joint use of MoLIC diagrams and mockups.
For the purpose of	Characterizing.
With respect to	• Quality of the artifacts produced. • Perception about the ease of use. • Perception about usefulness.
From the viewpoint of	Researchers in HCI.
In the context	HCI design.

Still in the planning, we defined the resources needed for the implementation of study, as follows:

Environment. Participants used MoLIC Designer[2] for building MoLIC diagrams and Balsamiq Mockups[3] for building mockups. They were conducted in an academic environment, where new technologies are usually tested before being transferred to industry (Shull et al., 2001).

Input Artifacts. We created the consent forms, two different interaction scenarios for a problem in the context of a Web application and, based on that, MoLIC diagrams and mockups. The group of participants who received a scenario and a MoLIC diagram created the corresponding mockups, whereas the group of participants who received a scenario and mockups should create the corresponding MoLIC diagram. Moreover, we created a post-study questionnaire to collect data on each participant's perception on each employed approach.

Participants. 13 students (undergraduate in the final year of course in Computer Science and graduate in Informatics) were selected who had little or no knowledge about the construction of mockups or interaction modeling.

[2] https://code.google.com/p/molic-designer/
[3] https://balsamiq.com/

Training. We provided training on both interaction modeling using the MoLIC language and user interface design using mockups.

3.2 Case Study Implementation

The study comprised in two steps, where each group performed a different activity in the construction stages of MoLIC diagrams and mockups, as shown in Table 2. Participants were randomly divided into two groups, where the undergraduate students are P1-P4 and the graduate students are P5-P13. Before the study, everyone signed a Consent Form, agreeing to make their data available for further analysis.

Table 2: Study groups and steps.

Group	Participants	1st Step	2nd Step
A	P3, P4, P7, P8, P9, P11, P12	from mockups to MoLIC	from MoLIC to mockups
B	P1, P2, P5, P6, P10, P13	from MoLIC to mockups	from mockups to MoLIC

Each participant worked individually, using computers with the tools installed. Each group performed the activity separately from the other groups, taking an average 90 minutes.

4 ANALYSIS OF THE RESULTS

The results of the experimental study were analyzed from two perspectives, detailed in the next subsections: (a) the quality of the artifacts produced based on the analysis of defects; and (b) the participants' perception on the usefulness and ease of use of each approach. To analyze the quality of the artifacts, a researcher examined the artifacts produced in step 1 and another researcher examined the artifacts produced in step 2 in search for defects. They later gathered for a peer review of defects found; and discussed the categorization of defects according to taxonomies of defect types adapted from Travassos et al. (2001), as presented in Table 3.

Table 3: Defect taxonomy for each artifact (Art.): MoLIC diagrams (ID) and mockups (M).

Defect Types	Art.	Description
Omission	ID	The omission or negligence of any information necessary to solve the problem in the interaction diagram.
	M	The omission or negligence of any information needed for the mockup solution.

Table 3: Defect taxonomy for each artifact (Art.): MoLIC diagrams (ID) and mockups (M) (cont.).

Defect Types	Art.	Description
Ambiguity	ID	A poor definition of certain information in the interaction diagram, which may lead to multiple interpretations.
	M	A poor definition of certain information in a mockup, which may lead to multiple interpretations.
Incorrect Fact	ID	Misuse of the elements from the interaction diagram for the interpretation of those involved.
	M	Misuse of the interface elements during the mockup development, allowing an incorrect interpretation of them.
Inconsistency	ID	Conflicting information between the elements of the interaction diagram and the information needed to solve the problem
	M	Conflicting information between the elements of the mockup and the information needed to solve the problem.
Extraneous Information	ID	Unnecessary information included in the interaction diagram.
	M	Unnecessary information included in the mockup.

Figure 3 shows the number of defects found in MoLIC diagrams and in mockups, classified by type, which are discussed in the next subsections.

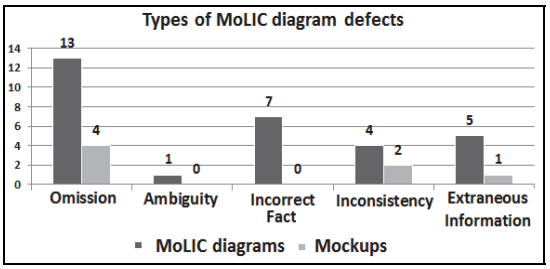

Figure 3: Number of defects by type and by artifact.

4.1 Defects in the MoLIC Diagrams

In this subsection we described all defects found in MoLIC diagrams, for each defect type:

Omission. Regarding the scene element, the main defect found was not specifying a scene for one or more user goals detailed in the given scenario. This means that the participant did not capture all of the goals that the user could achieve with the system. Regarding the scene details, participants failed to: specify dialogues; describe the dialog structures (XOR, AND, SEQ and OR); indicate the sign issuer used in the case of (d+u:); and represent some signs given in the interaction scenario. The transition element got more omission defects, and of different types, such as omissions of: utterance (or the utterance issuer) when switching from one scene to another; system processing, when some internal process was necessary to handle the user request; and breakdown utterance, when breakdown recovery was necessary after a system process. Some participants omitted the ubiquitous access (or its corresponding utterance) and opening point elements, without which the user interaction with the system would be quite limited.

Incorrect Fact. Regarding the scene element, participants used verbs that did not represent the user goals, but the system goals. Again, most of the defects in this category were related to the transition element, for instance: representing the wrong issuer of a transition utterance after a system process (using "u:" instead of "d:"), that is, as if the user were providing a feedback after an internal system process when, in fact, the designer plays this role; or after a scene (using "d:" instead of "u:"). In breakdown recovery utterances, instead of using dashed lines, participants used solid lines that represent regular transition utterances. Regarding the system process, system decisions were not detailed to represent alternatives of the system, but only a single possible feedback, without considering that the system process must provide recovery utterances for potential communication breakdowns. The ubiquitous access element was incorrectly used as the beginning of the user interaction, in place of an opening point.

Extraneous Information. Some scenes, transition utterances, and preconditions that were not described in the interaction scenario were represented in the mockups. Also, in the scene dialogs, we identified defects such as the detailing of the issuer preceding each dialog, although it should precede signs instead of dialogs. The closing point element was needlessly represented more than once.

Ambiguity. The only defect found was related to the use of two user transition utterances for the same goal, which provided multiple interpretations about the user transition.

Inconsistency. Regarding the dialogue scenes, dialogue structures of the MoLIC language (XOR, AND, SEQ, and OR) were inconsistent with the scenario (e.g. using AND instead of XOR). The direction of some transitions were inconsistent with the sequence of interaction scenes in relation to what was described in the interaction scenario. Regarding the signs, some of the sign issuers were attributed to the user or to the designer's deputy in a inconsistent manner with what was described in the interaction

scenario or represented in the mockups (i.e., confusion between "d:" and "u:").

4.2 Defects in the Mockups

From Figure 3, one may notice that the only types of defects found in the mockups were: Omission, Inconsistency, and Extraneous Information.

Omission. Some participants did not develop the mockup representing the main screen described in the interaction scenario, and the breakdown handling elements represented in the MoLIC diagram were not represented in the mockups. Furthermore, not all signs in the scenes were represented in the mockups, including required fields, which make the mockups incomplete and prevent the user to achieve a certain goal. Some ubiquitous accesses were not mapped, e.g., onto navigation bars or menu items.

Inconsistency. Some dialogues detailed in the scenes were mapped onto inconsistent elements in the mockup that are inconsistent with the dialogues described in the scene. And some breakdown utterances were mapped onto the mockups in an inconsistent way with respect to what was detailed in the MoLIC diagram.

Extraneous Information. Some pieces of information in the mockup went beyond the specification of a scene depicted in the MoLIC diagram and the interaction scenario.

4.3 Dicussion about Defects in the MoLIC Diagrams and Mockups

We could observe that there was a greater number of defects in the MoLIC diagrams than in the mockups. Moreover, we noticed more difficulties when the participants had to create the MoLIC diagram. A possible explanation is that the MoLIC language notation is less known by the participants and the mockups are similar to what system users see while interacting with systems.

For more details about the defects found in the MoLIC diagrams and mockups, as well as the severity of each defect, please refer to the technical report available at (Lopes et al., 2015). To better understand the participants' perception about the approaches used, we analyzed the post-study questionnaires, as described in the following subsection.

4.4 Analysis of the Perception about the Ease of Use and Usefulness of the Approaches

The post-study questionnaires were prepared based on the statements of the TAM model (Technology Acceptance Model), which has been widely applied to a large set of new technologies (Venkatesh et al., 2003). According to Laitenberger and Dreyer (1998), to investigate the acceptance of the users about a given technology, a model is necessary to demonstrate people's attitudes and behaviors.

On the questionnaire we employed a six-point scale, ranging from totally agree to totally disagree about the perceived ease of use (E1 to E5, Figure 4) and perceived usefulness (U1 to U6, Figure 5) of each approach to the participants answer. As suggested by Laitenberger and Dreyer (1998), we did not use an intermediate level because it would not provide information regarding the inclination (either positive or negative) of the participants.

E1 – It was easy to learn how to prepare the artifacts by following this approach to interaction design.

E2 – I managed to prepare the artifacts following this approach the way I would like during interaction design.

E3 – It was easy to gain skill in the elaboration of the artifacts by following this approach to interaction design.

E4 – It was easy to remember how to elaborate the artifacts by following this approach to interaction design.

E5 – I find it easy to elaborate the artifacts by following this approach to interaction design.

Figure 4: Post-study questionnaire on ease of use.

Participants also answered open-ended questions, through which they could cover topics about difficulties found during the study. Those answers were important to better understand the quantitative results obtained from the answers to the statements of the TAM model.

Figure 6 illustrates the results of statement E2. Although most of the participants have agreed with statement E2, there was a partial disagreement of 38% when they built the MoLIC diagram based on mockups. We highlight the following answers to the question "I. Which items of the MoLIC diagram didn't you identify directly from the mockups (but only from the interaction scenario)?":

"The interaction flow was not identified directly from mockups" (P2)

"The closing point, which in the case would finalize the interaction, was not identified directly from the mockup" (P6)

U1 – Elaborating the artifacts following this approach facilitated the interaction design.

U2 – I consider this approach useful for interaction design.

U3 – Elaborating the artifacts following this approach helped me to understand the process of interaction design faster.

U4 – Elaborating the artifacts following this approach improved my performance in the interaction design.

U5 – Elaborating the artifacts following this approach increased my productivity in interaction design (I believe that I have identified more aspects of interaction in a shorter time than it would take without using this approach).

U6 – Elaborating the artifacts following this approach increased my effectiveness in the interaction design (I believe that I have prepared an artifact in a more complete way using this approach than if I had not).

Figure 5: Post-study questionnaire on usefulness.

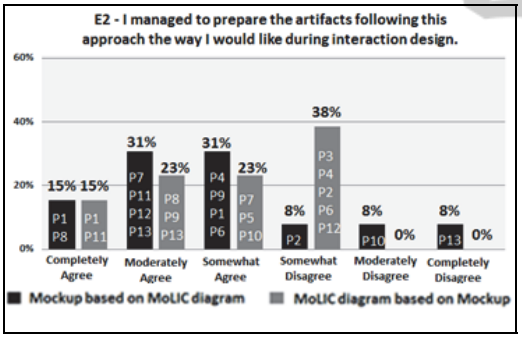

Figure 6: Answers to E2 – I managed to prepare the artifacts following this approach the way I would like during interaction design.

Regarding the creation of the mockups based on the MoLIC diagram, in response to the question: "II. Which items from the mockups didn't you identify directly from the MoLIC diagram? (but only from the interaction scenario)?", we cite:

"I did not identify which fields were required" (P4)

"I did not notice that the login could be done with the user name, social security number or email" (P12).

Although these participants had agreed about E2 when they had buit mockups, the quotes by P4 and P12 reflect difficulties to understand the MoLIC notation: the participants did not understand or did not remember the meanings of the dialogue structures (AND, OR, XOR, etc.).

Figure 7 depicts the results of statement E5. We can notice that the construction approach of mockups based on MoLIC diagram obtained a higher level of total agreement, 38% in relation to the construction of approach of the MoLIC diagram based on mockups (8%).

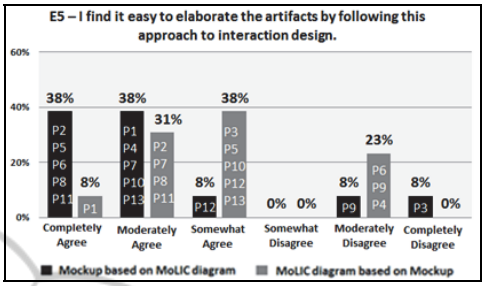

Figure 7: Answers to E5 – I find it easy to elaborate the artifacts by following this approach to interaction design, regarding ease of use.

However, both approaches showed some indications of disagreement. To investigate the total disagreement result of 8% and wide disagreement of 8% in relation to the creation of mockups based on a MoLIC diagram, we highlight some answers to the question: "III. What are the difficulties encountered during the construction of the mockups based on the MoLIC diagram?":

"Sometimes I had a doubt whether a particular interaction is done by the user or by the system "(P5)

"I was not sure about the necessary amount of mockups, or if it would be possible to represent the breakdown handlings in the same mockup" (P7)

Regarding the creation of a MoLIC diagram based on the mockups, 23% of the participants widely disagreed with E5. In response to the question "IV. What are the difficulties encountered during the construction of the MoLIC diagram based on the mockups?", we cite:

"It was hard to remember the MoLIC notation" (P6)

"I found it a bit hard to define the user goals on the scenes, because the user goal is not always the title of the screen, but this is the impression caused when the construction is based on the mockup" (P9)

Figure 8 illustrates the results of U2. One may notice a high level of agreement between the two approaches. We can also notice that 31% of the participants disagreed somewhat or moderately that creating the MoLIC diagram based on mockups is useful. And only one participant disagreed that creating mockups based on the diagram is useful for interaction design.

In the general open question, "V. You can help us by describing the positive and negative aspects about the usefulness of this approach to interaction design, especially if you think that using this

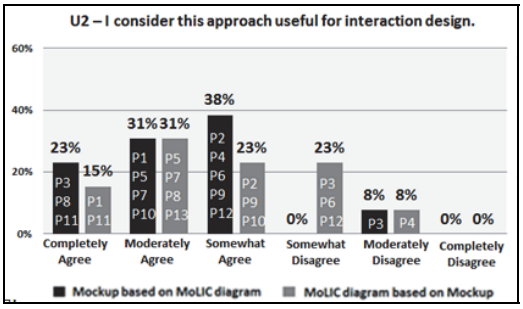

Figure 8: Answers to U2 – I consider this a useful approach for interaction design.

approach facilitated interaction design", we find that, for the approach of creating the MoLIC diagram based on mockups:

"MoLIC helps to understand concepts and it can help before the construction of the mockup in order to prevent waste of time to correct design errors" (P3)

"I find it easier to build the mockups based on the MoLIC diagram, than the reverse process" (P6)

Conversely, for the approach of creating the mockups based on the MoLIC diagram, we highlight:

"The approach facilitated the design of the interaction, since the mockups' elements were described in the diagram. Thus, it was not necessary to think a lot about the mockups" (P4)

"MoLIC is easy to understand, but I believe that in the case of a really big Project, the effort to create a diagram will be much higher than with other design options" (P5)

In summary, although some participants found that MoLIC diagrams were not so easy to build, most participants considered the MoLIC diagrams useful both for understanding the interaction design (i.e., valuable as an epistemic tool) and as a basis for creating mockups. Moreover, considering the number of defects found, our study also provided indications of the effectiveness of the approach of creating mockups based on MoLIC diagrams, but not the reverse.

5 CONCLUDING REMARKS

This paper presented an empirical study regarding the joint use of MoLIC diagrams and mockups to evaluate the combined use the artifacts from the point of view of undergraduate and graduate students. The results showed different defect types identified in MoLIC interaction diagrams and mockups. We noticed that the highest occurence of defects happened in the mapping from mockups onto interaction diagrams. The results also indicates that the approach of creating mockups based on MoLIC diagrams is more useful for providing understanding about the interaction and interface during HCI design.

In any case, the large number of defects in MoLIC diagrams highlighted the need of assess the quality of these artefacts. We are currently developing an inspection technique to help detect and correct defects in MoLIC interaction diagrams in a systematic way and in early stages of the development process, to achieve more consistent interaction modelling. Furthermore, we argue that interaction modeling, along with the mockups, gives the designer a clearer view of how the user interface will present the system and how the communication between the user and the user interface may occur.

As future work, we intend to execute a new empirical study with experienced designers, both to evaluate the cost/benefit of using MoLIC diagrams and mockups in interaction and interface design, and to compare MoLIC diagrams with other artifacts for the development of interactive systems.

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