Comparing Novice and Expert User Inputs in Early Stage Product Design

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Abstract: This research examines similarities and differences between expert and novice user inputs during early stage concept design and ideation. Using a mixed-methods approach, we obtained and analyzed user inputs from 18 nurses (9 novices and 9 experts) for the design of an intramuscular drug delivery system. Users completed semi-structured interviews and two questionnaires to document design inputs through written and oral descriptions, and to rank their top five design requirements. We coded design inputs per the categories of nurse safety, patient safety, usability, and functionality, and used Pearson's Chi-squared analysis to test for independence between the novice and expert groups. The data illustrate a significant difference in the frequency of usability and functionality requirements between the two user groups. Novice users cited requirements associated with product usability over two times as often as did expert users (39.4% vs. 17.1%); and experts cited requirements associated with product functionality over two times as often as did novices (35.4% vs. 16.7%). For the design of complex systems, this research captures the unique contributions that novice and expert users make to the design process, and highlights the importance of considering potential user input biases during early stage design.

Key words: User-Centered Design, Design Inputs, Early Stage Innovation, Medical Systems

1. Introduction

This research examines design inputs obtained from expert and novice product users during early stage concept design and ideation. It is part of a multi-phase research effort aimed at examining the contribution of users at discrete phases of the product development process. This work was motivated by an interest in identifying which users and user groups to target for the design of complex products and systems, intended for adaptive product use environments [2].

In this study, we focus on the design of an intramuscular drug delivery system, based on inputs (e.g. user-specified design requirements)[1] obtained by nurses with varying degrees of experience in the healthcare field. We are interested in exploring: 1) similarities and differences in design requirements between users of each group, with respect to task-based requirements and product attributes, and 2) if a qualitative difference exists regarding the originality and depth of design inputs obtained from expert and novice users.

1.1 Background and Motivation

[1] Design input, design requirement, user input, and user need are used to denote user-specified design requirements.

The notion of "user" is central to design methods and approaches. According to von Hippel [12] seventy-five percent of the commercially successful industrial goods innovation projects were user-driven, rather than technology driven. Depending on the extent of user involvement, there is a continuum of user concepts spanning from a concrete existing user (e.g. lead user) [12, 13]; to a participatory designer with whom one may directly interact [1]; to an abstract conceptualization of users as customers in axiomatic design [6]. Since users play a critical role in determining the success of a product and its impact on a community, the selection of the 'right user group' during the design process is critical for the success of any design method. The 'right user group' may vary from one industry to another and from one product to another; and there may be more than one 'right user group' for the same product within the same industry.

The role of expert and novice users in product design has been previously examined in the field of human-computer interaction (HCI), and in product development literature. In HCI, differences between novice and expert inputs for the design of graphical user interfaces have been extensively explored [4-5, 7-8]. Nielsen [7], for instance, showed that expert users are defined as individuals who have rich interaction knowledge, task knowledge, and domain knowledge of a specific system, and who are skillful in obtaining and using such knowledge to achieve goals or tasks in an interaction. Novice users, in comparison, have been defined as users who are naïve about a specific system, have less interaction experience, and appear unskillful in using and obtaining knowledge to achieve interaction goals and tasks.

In product development literature, the role of novice and expert users has been documented within the established field of lead-user innovation [12, 13]. Lead users are described as individuals or organizations, who experience needs for a given innovation earlier than the majority of the target market [13], and who are positioned to benefit from obtaining a solution to those needs.

Yet, conflicting views regarding the role of lead and expert users in product design highlight the need for continued research in this area. Ulwick [11], for instance, described that, "lead users can offer product ideas, but since they are not 'average' users, the products that spring from their recommendations may have limited appeal." Similarly, a retrospective analysis of eight medical device firms [9, 10] illustrated that companies often prefer to work with industry thought leaders during the conceptual design and product testing phases of development. However, surgical procedures developed primarily based on input from lead-user surgeons often resulted in the development of technology that was difficult for a broad range of product users to embrace. To close the usability gap between first and second-generation products, the companies studied implemented post-market revisions based on feedback from "average" users in the clinical field.

To further investigate disparities regarding the influence of novice/average and expert/lead users in product design, this research examines the inputs of users from two extremes of the experience spectrum during early stage concept design and ideation. Through a prospective cohort study, we examine the unique ways in which users' varying degrees of expertise influence design requirements, as well as the usability and functionality of designs produced. We aim to provide insight into factors that constitute differences in user inputs between groups, as well as possible explanations for "why" such differences exist. To build on research in graphical user interface design, this study documents the benefits of engaging novices and experts in the design of three-dimensional products, intended for daily user interaction across a range of product use environments (e.g. hospitals, clinics, and patient homes). By evaluating the impact of user expertise in early stage product design, this research provides an improved understanding of users' roles for the design of complex systems, and new insights regarding user-centric design teams.

2. Methodology

2.1 Research Questions

This research was guided by the questions: Within each targeted user group, which subjects should one design with and for during the product development process – a technologically adept expert user or a novice user? How does the inclusion of particular users in the design process impact design requirements, and the features and attributes of new products and systems?

To examine these questions, we obtained user inputs for the design of a hand-held intramuscular drug delivery system (i.e syringe). This technology area was selected to study the design of a system with the following attributes: 1) adaptability - to serve the needs of multiple product end users and stakeholders (e.g. clinicians and patients) across a range of product use environments; 2) tangibility - a physical system intended for daily hands-on user interaction; and 3) complexity - a mechanical system involving the integration of multiple sub-systems.

2.2 Data Collection

We obtained design inputs from 18 nurses (9 experts and 9 novices) using a mixed methods approach. This study was conducted under protocols approved by the Human Subjects Research panel at Stanford University.

Nurses were recruited to participate in the study from the Gurnick Academy of Medical Arts. Each user participated in a 60-minute design input session at either the Stanford Center for Design Research (CDR) or the Gurnick Academy. During each session, users completed an initial survey to document their injection experience. Study participants were segmented into novice and expert user groups, based on each user's stated number of years of experience administering injections (novice: M=0.4, SD=0.7; expert: M=17.0, SD=11.5), and the approximate number of injections administered (novice: M=4.8, SD=8.0; expert: M=1092.5, SD= 1075.5). Since we were interested in segmenting nurses with respect to their skills and experience in using IM syringes, study participants were not differentiated with respect to their educational levels or highest degrees obtained (although this information was collected for reference).

Following the initial survey, we showed each user a brief video of the injection process, in order to frame the design exercise in the context of administering injections within a clinical setting. For approximately 30 to 45 minutes, each user participated in a semi-structured interview that was conducted by two researchers. During the interview, we asked users to describe their design requirements for an intramuscular drug delivery system through sketches, written comments, and oral descriptions. The research team took hand-written notes and videotaped each session to fully capture user inputs. Following the interview, users completed a post survey, in which they ranked their top five design requirements on a scale from 1-5 (with 5 being the highest) and documented their technology adoption profiles. Each nurse was compensated with a gift card for his or her participation in the study.

2.3 Data Analysis

Survey data, and the description and ranking of each user input, were manually extracted and stored in an MS Excel spreadsheet for data coding and analysis. Analysis of user inputs from the novice and expert groups involved a combination of quantitative and qualitative methods.

Data Coding and Quantitative Analysis. Two researchers manually coded interview data with respect to two domains. First, we temporally coded each user input with respect to nine stages of the injection process, to identify if task-based differences existed between the two user groups.

The nine stages included: 1) needle selection, 2) uncapping of the needle, 3) drawing-up the proper dosage, 4) barrel measurements, 5) needle insertion, 6) medication injection, 7) checking for blood vessels, 8) post-injection safety, and 9) device disposal. From the coded data, we determined the cumulative number of design inputs obtained from experts and novices that were associated with each stage of the injection process. Using a 2x9 contingency table, we used Pearson's Chi-squared analysis to test for independence between the two user groups.

The research team then manually re-coded each user input with respect to four categories that emerged from the interview data. These included: nurse safety, patient safety, usability (e.g., speed and efficiency), and functionality (e.g., accuracy). From this coded data, we determined the frequency and frequency distribution of user inputs from each group that were associated with each of the four design requirement categories. This was done for both un-weighted and weighted user inputs. Un-weighted inputs refer to the frequency of design requirements cited by users of each group. Weighted inputs refer to the frequency of user inputs scaled by a factor of 1 to 5, to reflect users' top ranked design requirements (based on a 1-5 point scale, with 5 being the highest). For the weighted and un-weighted design inputs, we constructed 2x4 contingency tables for user group vs. frequency of inputs per category. We used Pearson's Chi-squared analysis to test for independence between the novice and expert user groups.

Qualitative Assessment of User Inputs. A qualitative analysis of user inputs was conducted to examine the originality and depth of inputs obtained from expert and novice users. We coded design inputs with respect to 1) novelty of ideas, 2) degree of detail, and 3) subject matter/focus.

Ideas were categorized as novel if they presented at least one new feature or function that to our knowledge (and the users') is not widely implemented in the market, and which no more than two users mentioned. Detailed ideas contained at least two elements describing either a feature's functionality or implementation (e.g., two ways to implement a single feature or function, or two distinct features or functions that could be implemented.) Lastly, we coded user inputs with respect to the subject matter that they related to, such as needle size, safety cap, air bubbles, needle attachment, or ergonomics.

3. Results

The data included a total of 98 design inputs from the novice group, and 108 inputs from the expert group. The findings illustrate both similarities and differences in user inputs between the novice and expert groups, based on a combination of quantitative and qualitative evidence.

3.1 User Input Comparison at each Stage of the Injection Process

Figure 1 illustrates the number of unique user inputs (novices: 71 and experts: 66) associated with nine stages of the injection process. Per the Chi-squared analysis, the two groups did not significantly differ, with respect to the task-based design requirements involved in administering an injection; $\chi^2(8, N = 137) = 7.403$, $p = .494$. The data illustrate a range of shared or common inputs between users of each group, with a notable clustering of design requirements associated with post-injection safety, for both expert and novice users.

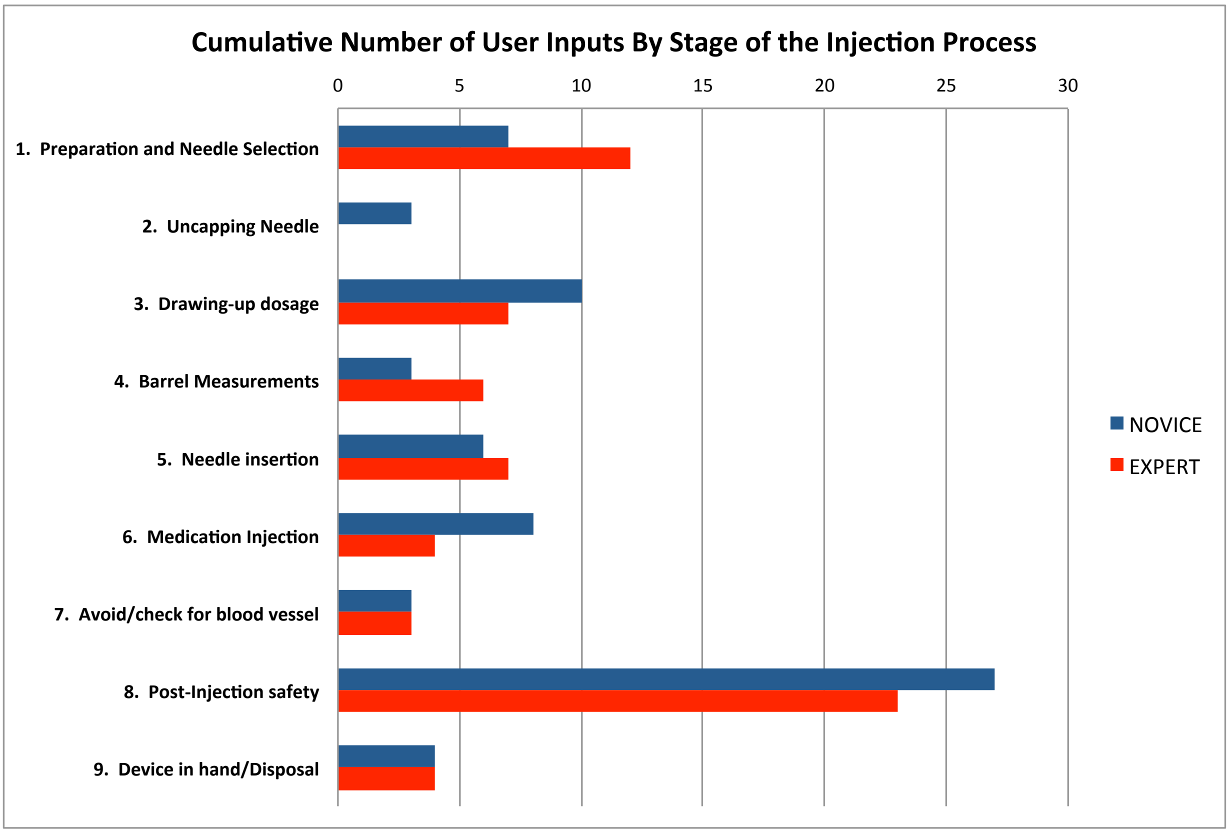

Figure.1 Number of user inputs at each stage of the IM injection process

3.2 User Input Comparison Across Categories

Un-weighted Data. Table 1 illustrates a comparison between the frequency and frequency distribution of un-weighted design inputs across the four categories of nurse safety, patient safety, usability, and functionality. With respect to these categories, novices cited 66 unique user inputs and experts cited 64. Per the Chi-squared test, the data indicate a significant difference in inputs between the novice and expert user groups; $X^2(3, N = 130) = 11.661$, $p = 0.009$. The un-weighted data illustrate that both novice and expert users expressed a comparable need for design requirements associated with nurse and patient safety. Yet, the percentage of novice user inputs associated with product usability is over twice that of experts (39.4% vs. 17.1%); and the percentage of expert user inputs associated with product functionality is over twice that of novices (35.4% vs. 16.7%). A graphical breakdown of un-weighted user inputs by category is shown in Figure 2.

Table 1. Un-weighted frequency count and distribution of user inputs per category

User Inputs	Nurse Safety	Patient Safety	Usability*	Functionality*
Novice, *n* (%)	15 (22.7)	14 (21.2)	26 (39.4)	11 (16.7)
Expert, *n* (%)	11 (17.1)	19 (29.7)	11 (17.1)	23 (35.4)

*Estimated 2:1 ratio between novice and expert users for these categories.

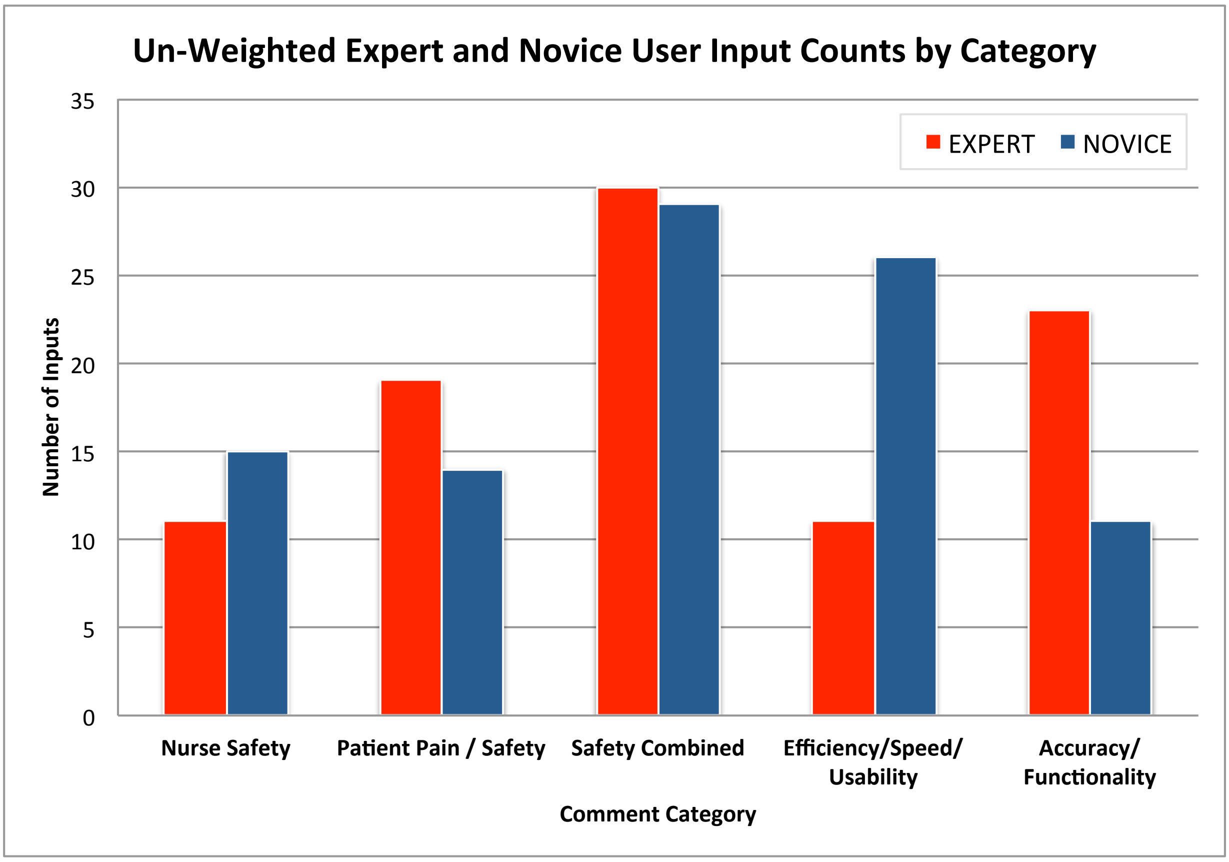

Figure.2 Number of un-weighted expert and novice user inputs, segmented by category

Weighted Data. The frequency and frequency distribution of weighted design inputs for experts and novices with respect to the four categories of nurse safety, patient safety, usability, and functionality is shown in Table 2. Similar to the un-weighted inputs, the data based on weighted user inputs (i.e. inputs scaled by users' top ranked design requirements) show that both novice and expert users prioritize product safety to a similar degree; yet a conflicting prioritization is seen between the two groups in regard to product usability and functionality. Per Figure 3, novices placed a greater emphasis on design requirements associated with product usability, and experts placed a greater emphasis on requirements associated with product functionality and accuracy (in nearly a 2:1 ratio per category). Per the Chi-squared analysis, a significant difference in inputs exists between the novice and expert groups with respect to the four categories; $\chi^2(3, N = 622) = 33.991, p < .001$.

Table 2. Weighted frequency count and distribution of user inputs per category

User Inputs	**Nurse Safety**	**Patient Safety**	**Usability***	**Functionality***
Novice, *n* (%)	70 (20.9)	79 (23.6)	118 (35.2)	68 (20.3)
Expert, *n* (%)	75 (26.1)	54 (18.8)	53 (18.4)	105 (36.5)

*Estimated 2:1 ratio between novice and expert users for these categories.

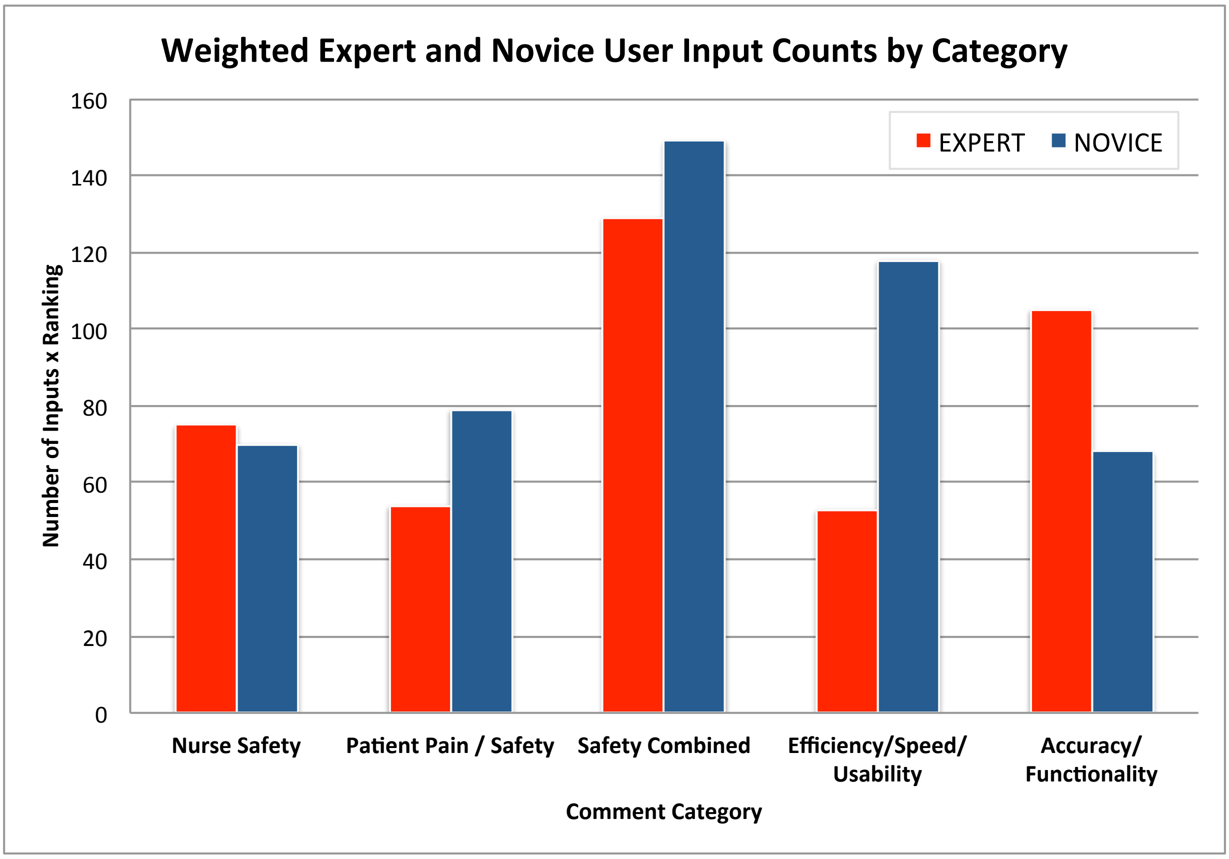

Figure.3 Number of weighted expert and novice user inputs, segmented by category

3.3 Qualitative Comparison of User Inputs

Novelty and Degree of Detail. Our data revealed differences between novice and expert users with respect to novelty of ideas presented. Novice users suggested 23 novel ideas, eight of which were described with at least two elements of detail. An example of a novel idea by novices was to synchronize the device with computerized medical records, so that it "automatically knows where/what/how much/what time for the injection." Others included the need for a depth gauge that makes "beeping noise sounds when you enter the muscle", a "way to insert the needle without feeling like you're inserting a needle, possibly like an ear-piercing gun," and "a needle shaped like a blade of grass." The novel ideas suggested by novice users often demonstrated originality and outside-the-box thinking, yet were not often grounded in mechanical details.

In comparison, the data showed that experts suggested nine novel ideas, four of which had two or more elements of detail. Novel ideas posed by experts included: administering the medication by inhalation (instead of injection), the addition of a magnifier on the barrel of the syringe that "can slide up and down to magnify a certain area of the markings," a type of "suction device attached to the syringe so a second hand is not needed to squeeze or stabilize the area," and a hinged "ball-like cover just beyond the end of the needle which locks so it can't be uncovered."

Subject Matter and Focus. Novice inputs were predominantly usability-focused, and often expressed concern for patient pain and discomfort. For instance: "[I need] some alert, possibly by chemicals in body, to let nurses know when the needle is in the muscle without having to aspirate;" and "[I] do not want a very thick needle in the arm because of pain … smaller and skinnier needles are easier for nurses to administer" (Novice Users).

The design inputs by experts also focused on usability factors: “When drawing up from the glass ampule, [you] need to first have a filter needle” (Expert). But inputs from this group were often extended to include mechanistic features associated with device functionality. For instance: “[I need] a needle that locks on as opposed to a slip tip with which medication can be lost when air is pressed out…a screw on attachment ensures the needle is not going to move or go anywhere” (Expert). The inputs from experts also included factors associated with patient pain and nurse safety: “Less pain would make the patient more cooperative, so easier for the nurse” (Expert User).

Additionally, we found patterns with respect to design inputs that focused on physical syringe attributes, among novices and experts. For both groups, user inputs most commonly focused on the safety cap, followed by the needle (size, shape, and presence). For expert users, the third most common focus was on syringe attributes related to measuring the medication fill; and the fourth most common attribute centered on the attachment of the needle to the syringe. For novices, the third most common inputs (in equal frequency) involved the attachment of the needle to the syringe and ergonomic concerns.

Among the less common areas of focus, novice users showed more concern with gauging the depth of the needle during injection, than did experts. Specifically, novice users’ inputs contained four depth gauge ideas (three of which were novel); where as only one expert user input offered a depth gauge idea, which was also novel.

4. Discussion

This research provides an in-depth analysis of user inputs obtained during the initial phase of product innovation, for the design of an intramuscular drug delivery system. To build on earlier research that retrospectively examines users’ contributions to product development, based on a product’s post-market performance, this work prospectively captures the unique contributions of expert and novice users at a discrete phase of the design process (i.e. during a ‘snap-shot’ in time within the design continuum). In addition, this study provides insights regarding the benefits of engaging users of varying degrees of expertise, particularly for the design of systems intended for multiple end users across a range of product use environments (e.g. hospitals and clinics).

The study’s findings showed that, from a task-based perspective, the number of user inputs associated with each stage of the injection process did not significantly differ between the two user groups. This finding highlights that both experts and novices were familiar with the steps involved in administering an injection. It also illustrates that a clustering of common inputs existed between the two groups, irrespective of user expertise. These inputs centered on factors associated with needle preparation, determining proper dosages, and post-injection safety.

In comparing the similarities and differences in user inputs with respect to the four categories (nurse safety, patient safety, usability, and functionality), this research showed that users of each group expressed a similar degree of concern for user safety. Although risk and safety concerns are less frequently examined in user interaction studies [3], this research highlights that product risk and user safety were important considerations among both novice and expert users, for the design of a tangible system intended for multi-user environments.

However, in regard to the importance of design requirements associated with product usability and functionality, significant differences were observed between the novice and expert user groups. Based on both the weighted and un-weighted data, novices expressed a greater need for design requirements associated with product usability, and experts expressed a greater need for functionality requirements (in approximately a 2:1 ratio for each category). It was also interesting to note that novice inputs centered on speed and efficiency, where as expert inputs focused on accuracy.

4.1 Practical Contribution for Designers

This study's findings provide designers with insight and empirical evidence regarding which user inputs to prioritize and focus on during the initial phases of the design process, and how the incorporation of specific inputs may impact the usability, functionality, and novelty of designs produced. Specifically, the data illustrate the importance of considering design inputs from two extremes of the user spectrum (extreme experts and novices), which may change over time with the addition of new knowledge and skills. The findings also illustrate the importance of considering common design inputs that are shared between users of both groups, and which tend to be static and un-changing (i.e.. inputs that primarily depend on a technology's core functionality).

For example, novice users predominantly focused on inputs associated with product usability. We view these inputs as *transient* in nature, since they have the potential to impact a large number of users initially, but eventually disappear over time with the addition of skill and experience. Expert users, however, focused on attributes associated with product functionality and accuracy. We view inputs in this group as *emergent*, since they emerge over time once a user has progressed to a certain skill level. A third group of user-specified design inputs, most often observed in our cohort of novice and expert nurses, were the core common inputs. These inputs were stable and unchanging over time, and often centered on a specific task that had to be completed, or on nurse and patient safety requirements.

In addition, the study's findings highlight differences in the novelty and creativity of inputs stemming from novice and expert users. For designers interested in exploring a large quantity of original, outside-the-box ideas, particularly in early stage design efforts, the data point to the beneficial aspects of engaging novice users. In contrast, for design inputs that focus on specific mechanisms of action, the data illustrate the benefits of including experts.

From these distinctions we argue that, on one level, there is a set of intransient inputs that are expressed by the majority of product users, which may guide designers in capturing core product requirements. Yet, on a higher level, there are inputs afforded by experts and novices that contribute to product functionality/accuracy and usability/speed/efficiency design criteria, respectively.

We posit that this separation in user inputs exists based on the characteristics of users at opposing ends of the experience spectrum. Expert users, on one hand, are less likely to identify usability flaws, since they have found mechanisms for adapting to or working-around usability-based challenges. Based on their experience, experts are more likely to identify potentially problematic and relevant usage scenarios that may contribute to the emergence of new design requirements from a technical perspective. Novice users, in contrast, are still in the process of mastering given tasks and are thus limited to contributing to user inputs at a more abstract (e.g. open-ended and less technically defined) level. As such, their inputs have not yet been 'blurred' by learned activities, and provide a wide range of novel and creative solutions. The study's findings suggest that design engineers, who are often experts in a technical field and potentially 'blinded' by experience, can gain valuable insights from novices, especially for building and refining user interface designs and user experiences.

4.2 Limitations and Future Work

Study limitations that warrant consideration include the sample size and geographic representation of study participants, and the medium used to capture user inputs. Although the research team analyzed a large sample of inputs (n=206) from the expert and novice groups, we believe that obtaining feedback from a wider range of nurses from diverse geographic locations would further enhance the generalizability of findings. Also, capturing user inputs through verbal or written comments (e.g. based on what users "said" they needed), as opposed to observing users in their natural setting, was a noted limitation. We believe further research is needed that examines differences in user inputs that are based on observing a user's interaction with people and physical prototypes within a user's natural work environment.

In the future, we aim to further assess the contributions of expert and novice users at discrete phases of the product design process, through actively engaging users in hands-on usability and functionality testing. We are also interested in examining user preferences toward designs that have been developed based on the inputs obtained in this study. Additionally, we plan to evaluate the insights gained from this research in a variety of industry domains, particularly those involving adaptive and rapidly changing user environments.

5. Conclusion

This study examines user-specified design inputs from expert and novice users, for the design of an intramuscular drug delivery system. We capture similarities and differences in design inputs, with respect to tasks associated with nine stages of the injection process, and with respect to four design requirement categories (patient safety, nurse safety, usability, and functionality). The results highlight that novices are more likely to reveal opportunities to improve the usability of a product, and experts are more likely to reveal functional gaps. This research also captures qualitative differences regarding the originality and depth of design inputs obtained from expert and novice users. The findings from this study contribute to literature in the product development field, and provide practical insights for the design of complex systems intended for multi-user environments.

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