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# Effect of User Information on Conceptual Design Thinking: A Linkographic Study

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## Abstract

*User-Focused design methodologies such as User-Centered Design advocate the need for understanding the user before creating design solutions. Designers employ various user research methods to understand their problems, needs, motivations, behaviours, etc. User information is collected and presented to designers at early stages of the design process; however, understanding users is only half of the job that designers need to ideate and come out with novel solutions to the problem in hand. This research aims to understand how user information, presented in the form of a persona, affects the design thinking process of a designer. A study was carried out with 17 industrial design students in which they were asked to solve a design problem with and without user persona. The participants were asked to think aloud while sketching conceptual design solutions for the problem. Verbal protocols from think-aloud sessions were used to create a total of 34 linkographs. The linkographs were quantitatively and qualitatively analyzed to observe differences in design thinking process while working with and without user persona.*

## Keywords

*Design Thinking, User-Centered Design, Protocol Analysis, Persona, Linkograph.*

# Introduction

Design has evolved from an intuitive to a research-based and process-oriented practice (Arnold, 2006). This is different from earlier design practices wherein designers would create solutions based on their own understanding of the design problem without taking the pain to conduct systematic user research. With the advent of participatory design approach followed by User-Centered Design (UCD) philosophy, designers are trained to view the design problem from the user's perspective in order to understand their needs, pain points and motivations before designing. Outcomes of user research are derived from intense efforts put by user-researchers in field-work. Hence, the data collected from user research is valuable and designers are expected to utilize it wisely as an appreciation to the rigorous work done.

In the design process, user research is only half of the work. Designers go back to their studios in order to develop creative solutions. Insights from user research is helpful for designers to make several design related decisions in order to create more User-Friendly products. However, it is still not very clear how designers use the data, collected from user research, to generate design solutions for a given problem (Anay, 2011). While information gathered from user research might assist designers and inspire them to think of novel design solutions, it might also act as a constraint resulting in them thinking conventionally. In either case, it is necessary to investigate how providing information about the users affects the design thinking process of a designer.

This paper reports findings from an experimental study done with design students. The aim is to observe how user information given in the form of user persona affects the design thinking process of a designer. This study is a step to understanding the differences in underlying cognitive processes when a designer creates a design solution with and without knowing their users. The understanding of cognitive processes involved in producing design ideas can help build efficient tools and techniques for designers assisting them in the design process (Jin & Benami, 2010). The outcomes of this study can be helpful in determining the factors contributing to the positive and negative effects of user information on design thinking. They also can further be used in developing new methods to collect or present user information to designers.

## User Information in Design

Taking users' perspective into consideration in the design process is not novel. History is full of anecdotal examples where users' needs were thoughtfully attended in the creation process of artefacts. For example, Hippocrates in Kat' Ihtreion (5th Century B.C.) suggested the design of a workspace for surgeons. Mayamatam, an ancient treatise on Indian architecture, suggests that dimensions of building elements be calculated based on the characteristics of the person living in the house (Dagens, 1985). With the advent of User-Centered Design (UCD) philosophy, the design process became more user-focused and the need to understand users became more important. This led to the rise in the development of sophisticated user research methods, tools and techniques. The growing need to understand users and acquire in-depth knowledge about user behaviour has brought user research a long way from survey questionnaire responses to advanced brain scan reports through sophisticated tools like Electroencephalography (EEG), Eye tracker, Galvanic Skin Response (GSR), etc. As a result, user research has now become a specialized field itself.

A typical UCD process starts with understanding and empathizing with the users, followed by problem definition, ideation, prototyping and testing. Depending on the design problem, user research data is required at various stages in a design process (Abras et al., 2004). However, user research done in the initial steps of the design process is more important for product development compared to other stages. This is because early user research helps designers appreciate design problems from a user's perspective and also acquire important information about users relevant to the problem. Therefore, when it comes to creating solutions in the next step, designers have a clear understanding of design objectives and goals.

## Design Thinking

Design literature presents diverse viewpoints on explaining the design thinking process (Ho, 2001). Design Thinking theorists explain the process as an act of creating or innovating, problem solving (Simon, 1995), changing a set of functions/requirements into description/design parameters (Gero, 1990; Liu & Lu, 2014), a dialogue between designers and artefacts/users (Kim & Ryu, 2014), relationship between the space of concepts and the space of knowledge (Hatchuel & Weil, 2009), a process to modify tentative or current design based on new information (Braha & Reich, 2003), decision making process (Nelson & Stolterman, 2014), act of *thrown-ness* or acting upon instincts in a situation (Heidegger et al., 1962), etc. Having a wide range of perspectives on the topic makes it difficult to define and more importantly assess or evaluate for study purposes. Therefore, to have a generic understanding, the term design thinking can be explained as an exploratory process which involves the creative agent to analyze the current problem situation and synthesize for novel solutions using available information.

Literature is abundant with various design thinking model proposed by philosophers and practitioners. For example, Koberg and Bagnall (1972) in The Universal Traveler, originally proposed five steps regarding design process which were expanded into seven steps namely accept, analyze, define, ideate, select, implement and evaluate. Design process model proposed by French et al. (1985) takes an engineering perspective of describing design process as an eight-step process ranging from need, problem analysis, problem statement, conceptual design, selected schemes, embodiment of schemes, detailing and working drawings. Cross (2000), also taking an engineering perspective, proposed a simpler design process approach based on the essential tasks performed by a designer. This model includes exploration, generation, evaluation and communication. Plattner et al. (2012) developed five stages of design process including the following: Empathize, Define (the problem), Ideate, Prototype, and Test. Nelson and Stolterman (2014) proposed six steps in design thinking namely desiderata (desire), interpretation and measurement (apprehend), imagination and communication (creating and visualizing), judgment (decision making), composing and connecting (giving form) also craft and material (producing artefact).

Most of the models and theories indicate two types of thinking processes that are involved in design thinking i.e., analytical thinking and creative thinking (Goldschmidt, 2016). Other terminologies used to explain the process include vertical and horizontal thinking transformations (Goel, 2014), ideation and evaluation (Basadur et al., 1990) associative and analytic thought (Gabora, 2010) also divergent and convergent thinking (Goldschmidt, 2016). The term convergent thinking signifies thinking that draws together information from many sources focused on solving a problem. When an individual tries to make sense of a piece of information in order to come to a conclusion, they engage in this kind of thinking process. Divergent thinking involves moving away in diverging directions so as to involve a variety of aspects leading to novel ideas and solutions (Goldschmidt, 2016). This style of thinking is noticed when designers are trying to come up with design concepts in a brainstorming session. It has been argued that design thinking involves interplay between divergent (creative) and convergent (analytical) thinking processes (Baer, 2003; Roberto, 2000). Both processes are equally important and are complementary to each other, as Owen (2007) argues that analysis is required to perform synthesis.

Kim and Ryu (2014) posit that a user-oriented design approach envisions design thinking as three distinct activities called analysis, synthesis and evaluation (Jones, 1992). First, the designer analyzes a design scope through user studies — i.e., problem framing— then generates and synthesizes a solution using their creative ideas — i.e., problem solving— and finally evaluates the outcome with the participation of the user — i.e., evaluation (Alexander, 1964; Broadbent, 1973). As they both collect information and select whether information (analysis stage) or choice (evaluation stage) should be picked, the analysis and evaluation stages are linked to convergent thinking processes (Wong & Siu, 2012). The synthesis activity is associated with divergent thinking where novel ideas to solve the given design problem are explored. The three activities do not follow a linear path. In fact, these activities are cyclic in nature, with the steps of analysis, creation and evaluation potentially repeating themselves if the solution provided is insufficient to solve the problem (Wong & Siu, 2012).

Having a number of methods follow this cycle to structure their design process (Howard et al., 2008; Liu & Lu, 2014), the cycle of *analysis–synthesis–evaluation* is widely accepted to be the dominating pattern at early design stages (Cross, 2001).

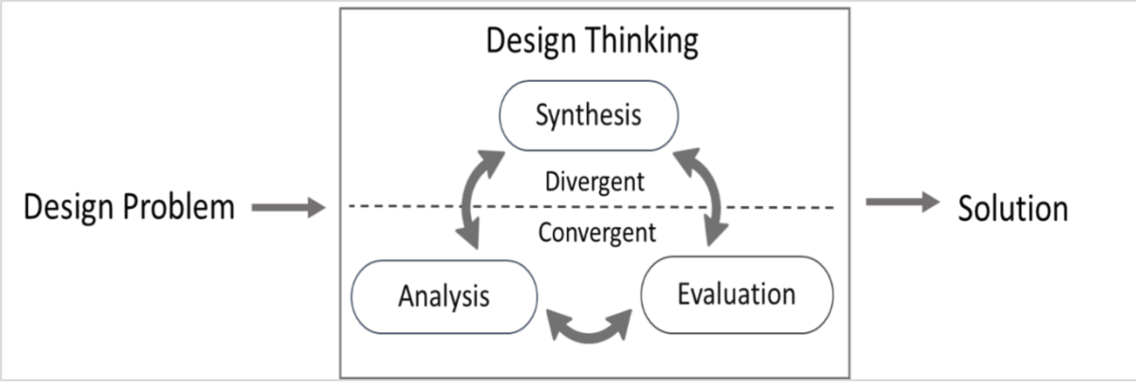


**Figure 1:** *Design Thinking Process.*

Based on the discussions above and taking various perspectives on design thinking into account, the authors agree with and espouse Arnold's idea of design thinking. Arnold's definition of creative thinking is as follows: *The creative process is a procedure of problem solving in which the creative agent seeks a novel solution to better satisfy basic human needs — capitalizing on a creative mindset and balancing all three thinking modes (analysis, synthesis and evaluation) along the way* (Thienen et al., 2017).

## Data Usage Supporting Design Thinking

The advancement of research to better understand users had significant contributions in terms of user data collection techniques, user data organization and data analysis methods. Yet, there are very limited methods that can guide designers to take forward user insights into succeeding steps in the design process (Anay M.O., 2011). This subject becomes necessary for novice designers and design students as design literature provides various sources where they can learn how to conduct user research but have limited education that can help in transferring user information into design. In order to create such knowledge, it is important to understand the cognitive processes involved in perceiving or interpreting user information.

## Related Works

Designers not having any idea about their users before user research is an inaccurate comprehension. Apart from personal experiences and clients' briefs, designers acquire user knowledge from various other sources like co-workers and experts, exchanging literature, previous design projects and case studies, etc. (Goodman et al., 2005). These sources help designers get a rough idea about their users. Özten (2011) explains that designers create user concepts which are basically knowledge structures *formed by the accumulation of personal experiences — experiences and knowledge about users provided by design education and practice*. It is further argued that user concepts provide frameworks which results in building user models that are basically designers' own mental model of users (Oygur, 2012). User models are *composed of collected user information, personal experience, experiences of co-workers and so forth* (Oygur, 2012). Hence, designers have an abstract idea about their users even before user research. However, user research is helpful in highlighting existing knowledge and/or adding new knowledge about users. According to Melican, user information can help evoke personal stories of designers which can further assist them in empathizing with user situations (Özçelik et al., 2012; Melican, 2000).

Researchers through various experimental and observational studies have investigated the effect of user information on designing activity. Oygur (2012) reports that user interaction and knowledge in the design process oscillates between being a source of inspiration and constraint. Further, So and Jaewoo (2017) reported that priming designers with user information helped them generate more original ideas.

Another study investigating the effect of persona on creativity declares that designers working with persona did not produce more creative drawings; however, working with personas may help designers increase confidence and user-centered attitudes (Lanius et al., 2020). Similar findings were reported by authors in another study where designers were asked to work on an HCI design problem with and without users. It was observed that designers working on design concepts with users underwent a richer design thinking process (Dahiya & Kumar, 2020). Another investigation on the effect of empathy exercise informs that designers underwent more cognitive actions while designing a graphical composition for a persona (Dahiya & Kumar, 2018). The studies stated in literature acknowledge differences in design thinking and eventually design solutions with the introduction of user information. However, the subject is still in very primeval stages of investigation and further exploration is needed. This paper aims to fill this gap by reporting a detailed experimental study on the subject.

# Methodology

In order to observe the differences in design thinking, designers' process of generating a conceptual solution was observed and analyzed. Similar methods have been used in design literature to understand the thinking processes in design tasks (Ahmed et al., 2003), creative ideation (Hatcher et al., 2018), fixation (Gero, 2011), etc. Since the authors were interested in studying design thinking process, brainstorming and design activities were studied instead of design solutions.

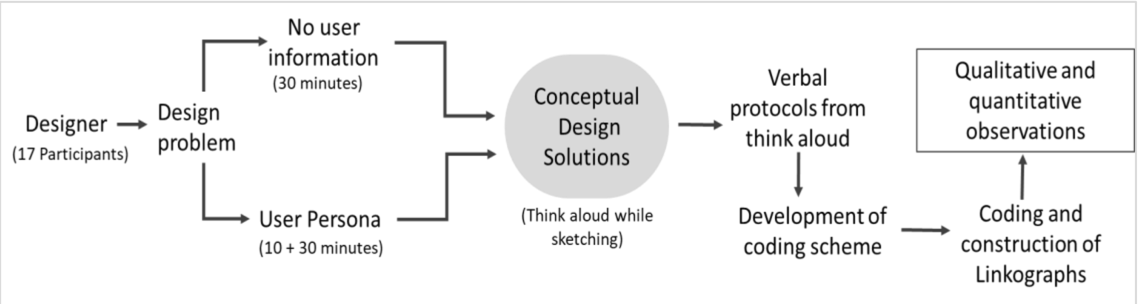


**Figure 2:** *Study Methodology.*

The participants were given two product design problems. The first problem was given without any user information and the second problem was given with user information in the form of a persona. The participants were asked to create conceptual design solutions for both design problems. While ideating for solutions, the participants were asked to think aloud. Verbal protocols from think-aloud sessions were recorded and analyzed by creating linkographs for both design sessions.

## Participants

A total of 17 industrial design students participated in the study (10 males, 7 females; average age: 25.3 yrs., Std. dev.: 1.23 yrs.) Participants were first year post graduate students studying Industrial Design. The participants did their graduation in engineering, architecture and design.

## Design Problem

A total of six product design problems were identified. These problems were to design;

**1.** A baby pram
**2.** A trekking bag
**3.** An airport luggage carrier
**4.** A grass cutting tool for gardener
**5.** A locomotive solution for the differently abled
**6.** A toolbox for a mechanic.

First three problems were randomly assigned to the participants, one problem per participant, when they were working in the first design session, i.e., without user information. Last three design problems were given to the participants, one problem per participant, in the second design session along with a user persona. Hence, each participant worked on two different design problems, the first without user information and the second with user information. Six design problems were selected instead of one or two because the authors were interested in observing participants' design behaviour in diverse design problems. Yet, it was ensured that the design problems are not too distinct from one another. While selecting design problems it was taken into consideration that the problems are workable in the given amount of time, have moderate complexity, have scope for novelty/practical applicability and have users associated with their use.

## User Persona

A user persona is a fictional user archetype that helps designers to get an idea about the users of their design solutions (Pruitt & Adlin, 2010). It is one of the widely accepted methods of user data presentation in the design industry. Short descriptions of users in the form of persona were created for the last three design problems. A case study with actual users was done before creating user personas in order to collect real problems that users encountered and also to make the persona appear realistic. Persona included a profile picture of the user and text describing the user's demographics, family background, work environment and problems they had faced. It is noteworthy that user persona, as a method of presenting user information, was chosen because of its ease of use and wide acceptance in the design industry.

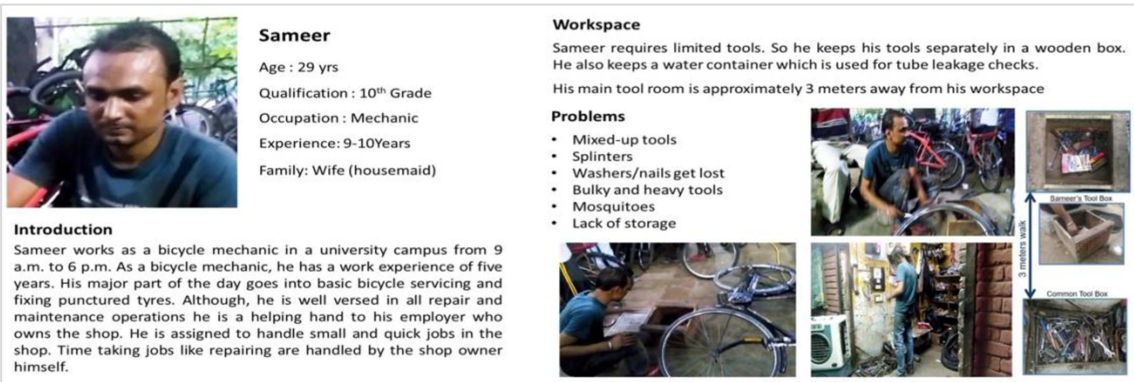


**Figure 3:** *User Persona Example Given to the Participants.*

## Study Procedure and Data Collection

The study was conducted in a controlled environment and the participants were given an isolated desk. It was ensured that participants' workspace does not have auditory or visual disturbances. A table top camera and a mic to record the session were installed near the workspace. The participants were briefed about the experiment and a signed consent form was obtained. The design problem was given to the participants on a printed paper along with the stationery required. The participants were given 30 minutes to complete the task and were instructed to design only conceptual solutions for the design problems. They were not allowed to use any sources of inspiration like pictures from the internet, magazines, books, etc. while designing the conceptual solutions for the given problem. The participants were asked to think aloud while creating design solutions. For those who were not familiar with the think aloud method, a small demo for think aloud was given to the participants. For those who were hesitant or uncomfortable with thinking aloud, an in-depth retrospective interview was conducted after the design session where they were asked to describe their design process in detail. Design sketches were used as cues to help in recalling their thinking process. A week later, the same participants were called again for the second design session. This time, they were first given a persona description and were given five minutes to read. After they were done reading the persona, the design problem was introduced. Participants were given similar instructions and were subjected to similar conditions as in the first design session.

## Data Analysis

Verbal protocols collected in design sessions were analyzed using linkography which is a method used to study a designer's cognitive activities. The method is based on interconnections between design actions expressed in a design process. The output is a visual representation of a designer's thinking pattern represented in the form of links. This technique is widely used in studies that aim to observe design thinking and creativity. In order to create a linkograph, verbal protocols are first parsed into design moves which is *a step, an act, an operation, which transforms the design situation relative to the state in which it was prior to that move* (Goldschmidt, 2014). Design moves are then linked based on their content, determining the relationship between them. A series of networks among design moves were produced and thus being a graphical representation of cognitive activities involved in solving the design problem. In order to create linkographs for the data collected, verbal data recorded in the design sessions was transcribed into text. Next, design moves were identified from the transcripts. Finally, linkographs were created by connecting design moves based on their associations with one another.

### Coding

Principal cognitive activities involved in design thinking namely analysis, synthesis and evaluation, were the basis for developing coding schemes. As described above, analysis is a preparation process where designers focus on interpreting and collecting relevant information to solve the problem, work out specifications and constraints of the problem (Kolodner & Wills, 1993) and break down or decompose design problem into several categories or sub problems (Rowe, 1987; Jones, 1992). Therefore, verbal protocols indicating such activities were coded as analysis activities. Synthesis activities are considered as compound activity that involves exploration of ideas to create design solutions. Accordingly, verbal protocols indicating new idea development, adding or altering features in design, associating with other examples or inspiration for idea development, etc. were coded as synthesis activities. Evaluation in literature is explained as *the test of the performance of new structures* (Jones, 1992). Evaluation is required in selection or expression of a preference for an idea (Runco & Acar, 2012; Goldschmidt, 2016). For the study, the verbal protocols indicating comparison, user acceptance and justification of a feature or solution were coded as evaluation activities. The principal tasks were further divided into design actions indicating design behaviour. A set of codes was developed on the basis of initial observations and by taking references from literature. Nonetheless, the authors were open to allow the coding scheme to evolve during the analysis. There were certain design actions that did not fall under any code described below. For example, participants talking about their personal interests/behaviour, sketching, design habits, etc. Such actions were not coded and therefore ignored in the further analysis.

**Table 1:** *Final coding scheme with examples.*

| Design Activity | Code | Design Action | Example |
|---|---|---|---|
| ***Analysis*** | Fo | Formulating design requirements | *It should be usable.* |
| | Re | Referring to design requirements | *Like I said, it should be visible upfront.* |
| | Us | Referring to user's behaviour/outcomes of user research | *He does not have a place to sit.* |
| | Es | Referring to existing design solutions | *Right now, he is using a stick as a support.* |
| ***Synthesis*** | Cs | Creating a new solution | *I am having an idea of creating a separate cube seat compartment/chair.* |
| | Af | Adding a new feature to a design | *Then I added some sun cover.* |
| | Al | Altering an earlier created solution | *Plastic handle rather than metal.* |
| | In | Referring external sources for inspiration | *I really connect leisure with nature.* |
| | Ex | Explaining the idea | *So as soon as you tilt it the body mass is shifted.* |
| ***Evaluation*** | Co | Comparing solutions or design features | *This is looking better than the previous one.* |
| | Js | Justifying a Proposed Solution | *That's why I just made two compartments.* |
| | Ua | Predicting about user behaviour/acceptance | *He might be confused with too many options.* |

Design moves in the linkograph were coded by authors on the basis of the coding scheme explained above. In order to reduce subjectivity in coding, two other experts were asked to code design moves. The two experts were given a sample of 100 design moves and were asked to code them using Table 2 as a reference. The two experts were senior research scholars in industrial design having industry experience of more than six years. It was ensured that the experts understood the meaning of each code before going ahead. In order to test the consistency of implementation of the codes, an inter-coder reliability test with two other experts was conducted. The inter-coder reliability was calculated using Fliess' Kappa, since there were more than two experts. Coefficient value k was found to be 0.603 (po=0.813, pe=0.528) which indicates a substantial agreement among the coders.

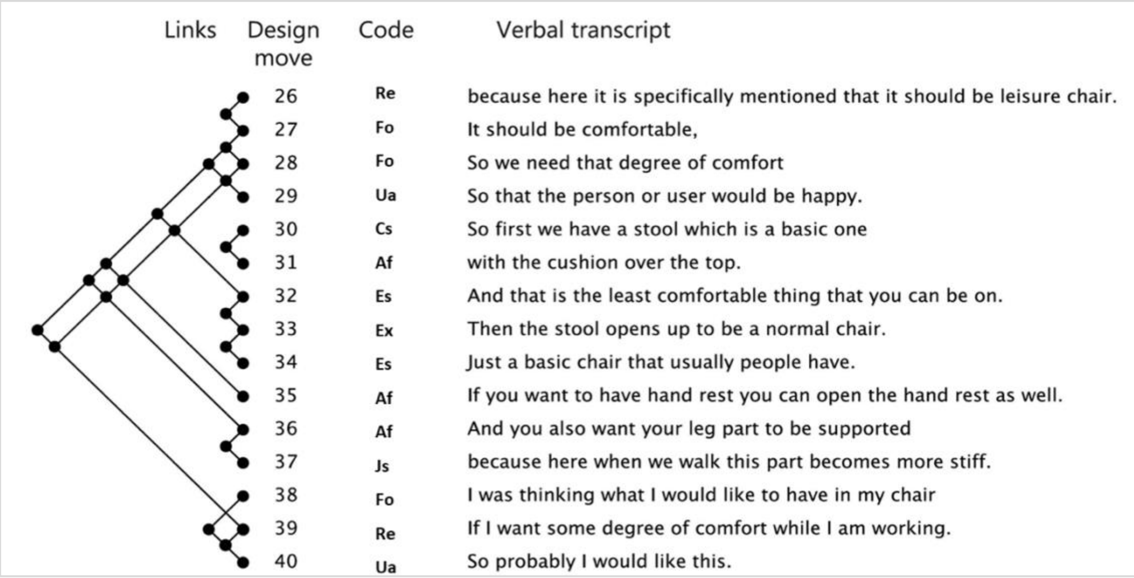


**Figure 4:** *Example showing development of coded linkograph from verbal protocols.*

# Results

**Table 2:** *Quantitative observations from linkographs for both design sessions i.e., working with and without User Information (UI).*

| | **Number of Critical moves** | | **Link Index** | | **Fore-link Entropy** | | **Backlink Entropy** | | **Horizontal Link entropy** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Without UI* | *With UI* | *Without UI* | *With UI* | *Without UI* | *With UI* | *Without UI* | *With UI* | *Without UI* | *With UI* |
| *Mean* | 4.41 | 6.71 | 1.31 | 1.73 | 0.298 | 0.329 | 0.351 | 0.385 | 0.120 | 0.163 |
| *Std. dev.* | 1.91 | 3.20 | 0.164 | 0.258 | 0.076 | 0.071 | 0.070 | 0.066 | 0.032 | 0.048 |

Critical Moves (CMs) in linkograph indicate important turning points in the thinking process. Link Index (LI) is defined as the average number of links per design move. A higher number of CMs and LI values are indicators of a structured design thinking process (Goldschmidt, 2016). Results show that the number of CMs and LI values are higher in second design session. This demonstrates that participants working on the design problem with user information underwent a more structured design thinking process than the other case. Entropy of idea links can be helpful in pinpointing the creative thinking behaviour of the individual (Kan et al., 2007). High link entropy is an indicator of a richer design thinking process. Gero defines a rich idea generation as a process having reasonably integrated and articulated structure of ideas and a variety of moves (Kan et al., 2007). It was observed that overall entropy values for second design session i.e., designing with user information were higher as compared to the first design session. This indicates that designers working on design problems with user information underwent a more creative thinking process.

## Coding Distribution

**Table 3:** *Code-wise average number of design moves in a linkograph for both design sessions.*

| Design Activity | Code | Without UI | | With UI | | P-value |
|---|---|---|---|---|---|---|
| | | Mean | Std. dev. | Mean | Std. dev. | |
| ***Analysis*** | Fo | 5.35 | 2.68 | 2.29 | 1.77 | 0.001 |
| | Re | 6.18 | 3.67 | 6.00 | 3.74 | 0.441 |
| | Us | 1.82 | 1.98 | 8.94 | 3.11 | 0.000 |
| | Es | 4.53 | 1.88 | 3.29 | 2.70 | 0.078 |
| ***Synthesis*** | Cs | 5.65 | 3.86 | 7.00 | 3.31 | 0.041 |
| | Af | 7.12 | 2.83 | 7.12 | 3.18 | 0.500 |
| | Al | 3.59 | 2.03 | 2.41 | 1.61 | 0.040 |
| | In | 2.18 | 2.41 | 1.76 | 0.88 | 0.245 |
| | Ex | 6.94 | 2.86 | 5.47 | 3.03 | 0.029 |
| ***Evaluation*** | Co | 1.06 | 1.00 | 1.82 | 1.25 | 0.003 |
| | Js | 1.88 | 1.45 | 5.82 | 3.96 | 0.000 |
| | Ua | 3.06 | 2.53 | 7.59 | 4.00 | 0.000 |

Table 3 shows coding distribution in linkographs i.e., average number of codes in a linkograph for both design sessions. It was observed that there were differences in coding distribution between first and second design sessions. For *Analysis* activity, the average number of design moves associated with formulating design requirements (Fo) and Referring to user's behaviour/outcomes of user research (Us) were found significantly greater ($p<0.005$) in the second design session. This indicates that designers working without user information were formulating their own design requirements when it is unavailable. Further, while analyzing, designers were mostly concerned with the outcomes of user research when the user information is available. Designers were also thinking more about existing design solutions when the design problems were provided without user information; however, the difference is not statistically significant.

While synthesizing, significant differences were observed when the designers were working on creating a new solution (Cs), altering previously created solutions (Al) and explaining the solutions (Ex). While there was an increase in the number of design moves for Cs in the session where designers were working with User Information, significant drip in the mean values of Al and Ex was also observed. The figures indicate that there were a greater number of attempts to create new solution when designers were working with user information. This correlates with the high entropic values of linkographs that were observed in the second design session. Another notable observation is that designers were going back to alter a previously created solution in the first design session. On the contrary, designers in the second design session were more satisfied with what they had created for their users and were not inclined towards changing the solutions.

Changes in evaluation activity among the two design sessions were significant as compared to the other two design activities. Designers were found to be evaluating their concepts more frequently when they were working with user information. Evaluation activity included design moves indicating comparison between design solutions (Co), justifying proposed solutions (Js) and predicting user acceptance or behaviour for the proposed design solutions (Ua).

## Link Distribution

The values given in Table 3 are only helpful in determining the design activity in which designers were mostly engaged during the session. To get a better picture of how one design activity is related to another, a matrix was developed. This matrix presents average number of links that occurred between the design activities. Table 4 and 5 present the link matrix developed for first and second design session respectively.

**Table 4:** *Code-Wise average number of links in a linkograph for first design session i.e., designers working without user information.*

| Design Activity | | *Analysis* | | | | *Synthesis* | | | | | *Evaluation* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Code** | Fo | Re | Us | Es | Cs | Af | Al | In | Ex | Co | Js | Ua |
| *Analysis* | Fo | 3.35 | 2.88 | 1.12 | 2.94 | 1.06 | 0.53 | 0.24 | 0.35 | 1.41 | 0.12 | 0.29 | 0.82 |
| | Re | 2.88 | 1.76 | 0.65 | 1.47 | 1.06 | 1.06 | 0.53 | 0.71 | 1.35 | 0.24 | 0.53 | 0.71 |
| | Us | 1.12 | 0.65 | 0.71 | 0.59 | 0.18 | 0.29 | 0.35 | 0.29 | 0.18 | 0.00 | 0.35 | 0.65 |
| | Es | 2.94 | 1.47 | 0.59 | 2.06 | 1.18 | 1.12 | 0.47 | 0.53 | 0.65 | 0.24 | 0.41 | 0.24 |
| *Synthesis* | Cs | 1.06 | 1.06 | 0.18 | 1.18 | 1.00 | 1.71 | 0.94 | 0.65 | 1.88 | 0.18 | 0.35 | 0.71 |
| | Af | 0.53 | 1.06 | 0.29 | 1.12 | 1.71 | 1.94 | 1.47 | 0.94 | 3.00 | 0.18 | 0.76 | 0.59 |
| | Al | 0.24 | 0.53 | 0.35 | 0.47 | 0.94 | 1.47 | 0.59 | 0.18 | 1.29 | 0.29 | 0.12 | 0.82 |
| | In | 0.35 | 0.71 | 0.29 | 0.53 | 0.65 | 0.94 | 0.18 | 0.76 | 0.41 | 0.00 | 0.18 | 0.41 |
| | Ex | 1.41 | 1.35 | 0.18 | 0.65 | 1.88 | 3.00 | 1.29 | 0.41 | 1.53 | 0.18 | 0.47 | 0.53 |
| *Evaluation* | Co | 0.12 | 0.24 | 0.00 | 0.24 | 0.18 | 0.18 | 0.29 | 0.00 | 0.18 | 0.18 | 0.12 | 0.18 |
| | Js | 0.29 | 0.53 | 0.35 | 0.41 | 0.35 | 0.76 | 0.12 | 0.18 | 0.47 | 0.12 | 0.35 | 0.53 |
| | Ua | 0.82 | 0.71 | 0.65 | 0.24 | 0.71 | 0.59 | 0.82 | 0.41 | 0.53 | 0.18 | 0.53 | 0.41 |

**Table 4:** *Code-Wise average number of links in a linkograph for second design session i.e., designers working with user information.*

| Design Activity | | *Analysis* | | | | *Synthesis* | | | | | *Evaluation* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Code** | Fo | Re | Us | Es | Cs | Af | Al | In | Ex | Co | Js | Ua |
| *Analysis* | Fo | 0.65 | 1.47 | 2.71 | 0.18 | 0.24 | 0.12 | 0.00 | 0.06 | 0.18 | 0.00 | 0.65 | 1.12 |
| | Re | 1.47 | 1.71 | 5.47 | 0.88 | 1.29 | 1.29 | 0.06 | 0.47 | 1.06 | 0.24 | 1.12 | 1.18 |
| | Us | 2.71 | 5.47 | 5.94 | 1.29 | 3.59 | 1.29 | 0.59 | 0.06 | 1.53 | 0.41 | 1.71 | 3.41 |
| | Es | 0.18 | 0.88 | 1.29 | 1.76 | 0.65 | 0.82 | 0.29 | 0.29 | 0.29 | 0.12 | 1.06 | 0.71 |
| *Synthesis* | Cs | 0.24 | 1.29 | 3.59 | 0.65 | 1.47 | 2.00 | 0.76 | 0.88 | 1.29 | 0.47 | 1.41 | 2.00 |
| | Af | 0.12 | 1.29 | 1.29 | 0.82 | 2.00 | 2.00 | 0.71 | 0.82 | 1.41 | 0.29 | 1.71 | 1.71 |
| | Al | 0.00 | 0.06 | 0.59 | 0.29 | 0.76 | 0.71 | 0.35 | 0.41 | 0.29 | 0.47 | 0.24 | 0.53 |
| | In | 0.06 | 0.47 | 0.06 | 0.29 | 0.88 | 0.82 | 0.41 | 0.47 | 0.24 | 0.06 | 0.35 | 0.35 |
| | Ex | 0.18 | 1.06 | 1.53 | 0.29 | 1.29 | 1.41 | 0.29 | 0.24 | 0.76 | 0.29 | 1.29 | 2.41 |
| *Evaluation* | Co | 0.00 | 0.24 | 0.41 | 0.12 | 0.47 | 0.29 | 0.47 | 0.06 | 0.29 | 0.06 | 0.24 | 0.47 |
| | Js | 0.65 | 1.12 | 1.71 | 1.06 | 1.41 | 1.71 | 0.24 | 0.35 | 1.29 | 0.24 | 0.94 | 1.88 |
| | Ua | 1.12 | 1.18 | 3.41 | 0.71 | 2.00 | 1.71 | 0.53 | 0.35 | 2.41 | 0.47 | 1.88 | 2.76 |

Comparing the two matrices, it can be observed that design moves associated with analysis activity were more linked to synthesis and evaluation activities when designers were working with user information, for example, Us-Cs, Fo-Cs, Fo-Ex, Us-Ua, Us-Js. Analysis moves were mostly linked with each other resulting in less linking to synthesis and evaluation activities when designers were working without user information. Synthesis activities in the first design session were mostly linked among themselves. Whereas they are more linked to evaluation activities in the second design session, for example, Cs-Ua, Ex-Ua, Af-Js. Evaluation activities were more associated with analysis and synthesis activities when designers were designing with user information. Differences in values of Ua-Us, Js-Us, Js-Cs and Ua-Cs in first and second design sessions are more evident.

Figure 5 presents a comprehensive picture of activity link matrix values given in Table 4 and 5. The values were obtained by taking the mean value of all the codes under the respective activity. A stronger relationship between analysis-evaluation and synthesis-evaluation was observed when designers were working with user information. Further, synthesis activities were mostly linked among themselves when designers were working without user information. This indicates that designers were building up ideas from previous solutions i.e., one idea is leading to the other. Whereas in the case where user information was available, designers were taking references from user information provided for them.

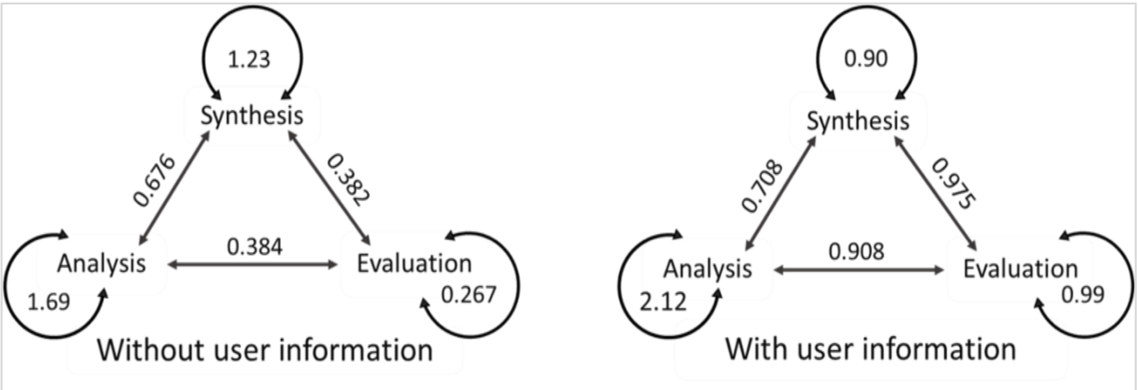


**Figure 5:** *Link distribution of design activities in two design sessions.*

## Design activity distribution

Chronology of coded design moves was studied to observe design activity distribution during the two sessions. Based on the frequency of a code in each design move, typical coding patterns for both design sessions were computed. Figure 6 presents the graphs that were plotted between design moves and the average coding pattern derived. For ease of understanding, the graph was divided into three segments. First segment majorly involves analysis activity in both design sessions. The difference is, while designers in first session were mostly formulating design requirements on their own, they were talking about users and their problems in the second design session. The second segment depicts ideation session as most of the design moves in this segment were observed in synthesis activity. The major difference in this segment is the oscillating nature of design moves. In the first session, design moves were mostly associated with synthesis activity. A few transitions between analysis and synthesis can be observed in the initial and final part of the segment. On the other hand, in the second session, it is hard to figure out the dominant design activity because design moves were taking frequent jumps from analysis to synthesis and evaluation. This explains high inter-activity link values between analysis-synthesis-evaluation that was observed (Figure 5) in the second session. Frequent transitions from analysis to synthesis activities in the first design session might indicate participants getting inspiration and translating it into design solutions early in the design process; while in the second design session, participants were evaluating before moving forward to synthesize design solutions. This demonstrates that user information can be limiting or constraining certain ideas. Only the ideas which are filtered after evaluation may be taken further by the participants. Although it is only a rough picture, deeply analyzing the type of design decisions is required to have more clarity in this area. The third segment depicts designers wrapping up their design sessions. A major difference that can be observed is that designers in the first session continued to explore and improve their ideas as in the second session they were mostly validating their designs. Designers were referring to design requirements that were formulated in the beginning of the session and cross-examining whether the proposed solutions would be helpful to their users or not.

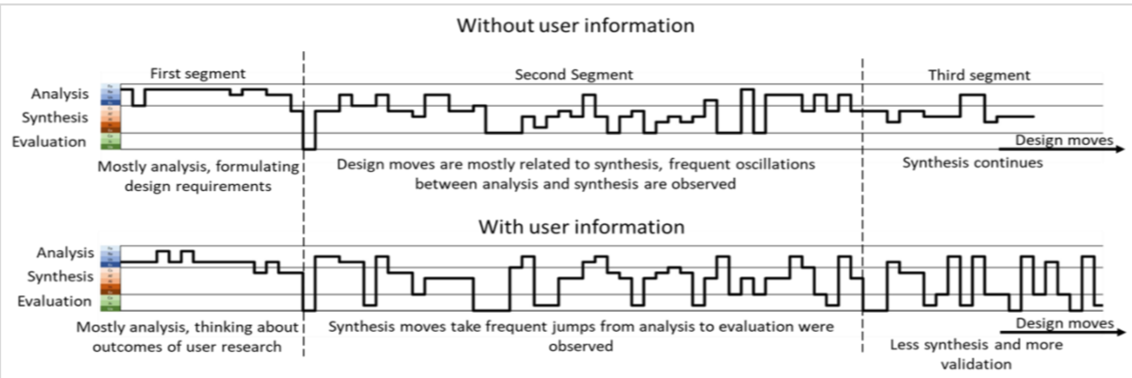


**Figure 6:** *Distribution of design activities in two design sessions in chronological order.*

## Discussion and Conclusion

Understanding users before designing has become a common practice in the design industry, thanks to the User-Centered Design philosophy. Nonetheless, it is equally important to examine the transformations in design behaviour due to such change. This paper aimed to discuss the effect of user information on design thinking. Though there have been several attempts to investigate what affects design thinking, this particular area is still not very well explored in literature. The study presented has made an attempt to experimentally investigate the change in design thinking behavior with the introduction of user information. Some key observations from the study are as follows.

First, user information helped designers improve the quality of their thinking process. Rise in number of CMs and LI values indicated that designers working with user information were able to have a more structured thinking process as compared to the case where user information was unavailable. The authors posit that one of the reasons for this is having an explicit understanding of users and their problems in the beginning of the design process, which might have helped the designers to organize their thoughts in the early stages of design. However, such conditions might also lead designers to fixate on primary ideas. Nevertheless, findings indicate that designers working with user information did not show signs of fixation as forelink entropy for the second session was higher than the first. Additionally, backlink entropy which is an indicator of novelty was found higher in the case where designers were working with user information. Cohesiveness in the design process indicated by horizontal link entropy was also higher when designers worked with user information. Hence, it can be concluded that providing user information along with the design problem helps designers focus on the problem better than when it is not provided.

Second, it was observed that designers, when not provided user information, formulate their own set of requirements based on their prior knowledge or experiences, whereas, they tend to refer more to user information when it is available. Availability of user information helped designers in saving their efforts to think of possible problems and other problem related issues. This not only saved time but also helped them formulate a structured task environment to work on the problem. An increase in the number of attempts to create and alter design solutions was observed when designers were working on the design problem with user information. Most of the design alteration decisions were based on the given user information — e.g., Table 4 and 5: Al-Us. Another important finding is that designers are more likely to evaluate their ideas when they work with user information. On the basis of these observations, it can be concluded that designers pay important attention to user information when provided. Also, user information is helpful in reflecting back on design solutions.

Third, apart from changing the way designers analyze design problems and evaluate their solutions, user information also changes the way they synthesize for solutions. It was perceived that when designers create solutions without user information, the idea generation process is mostly isolated from analysis and evaluation activities. In other words, solutions created were mostly incremental — as in one idea leading to another. Contrarily, designers working with user information were creating design solutions which took references from user research outcomes and pondering over initial design thoughts. The authors reckon that this could be due to continuous evaluation of design solutions. In the first design session, designers were unconfined to user requirements and therefore had more liberty to explore situation in diverse directions. This act of exploration was reflected in their solution generation behavior as an incremental process.

Based on the observations resulting from the study, this paper concludes that providing user information to designers, along with a design problem, influences the design thinking process of a designer. But, is user information also decisive in design decisions? To answer this, percentage of CMs were compared. It is observed that the percentage of critical moves associated with Us and Ua has increased from 4.76 to 25.62 and 6.35 to 14.88 respectively. Both the codes indicate design moves associated with user research. Hence, important design decisions were taken by the designers, keeping users in their mind.

## Limitations and Future work

User information and design thinking are very broad areas of research. Understanding the influence of one over the other requires multiple such studies. This study only takes persona as a format of user information whereas there are other formats in which user information is presented to designers. Further, the study only considered explicit user information that is provided to the designers and does not take designers' implicit user knowledge into account. The study used think-aloud protocols to analyze design thinking. Concurrent verbalizations are often criticized for obstructing the natural thinking process. Furthermore, many studies reported in literature have used the method because it is helpful in revealing details of sequences in which information processes reflect the designer's short-term memory. With the introduction of physiological tools like EEG, Eye tracker, etc. such limitations can be minimized. The study was also limited to a homogenous group of novice designers with a limited range of product design problems. Deeper observations on how skilled or experienced designers utilize user input is a further area of research that requires attention. A forward step in this question could be understanding what type of design decisions are taken by designers when they refer to user information. Moreover, a range of other design problems in other design fields like architecture, HCI design and graphic design can be explored.

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