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**Personal Research Grants**

**Research Grant Application no. XXXX/XX**

## General application information

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| **Role** | **Name** | **Academic Rank** | **Department** | **Institute** |
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**Research Title**

How does framing and reframing in design problem-solving affect the quality of solutions

involvement in social commerce: The struggle between barriers and motivation

**Keywords**

Frame; framiing; reframing; design thinking; problem-solving; expertise; protocol analysis; FBS; xxxx

**Requested Budget in NIS**

3

No. of Years

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Average Annual Budget

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Name & Position

Signature & Stamp

Date

Application No.

PI1 Name: Hernan Casakin

Scientific abstract – *How does framing and reframing in design problem-solving affect the quality of solutions*

Framing and reframing (F-RF) is a fundamental cognitive activity that occurs across all problem-solving fields and has been studied qualitatively in design and innovation. Frames are a set of grounded, co-activated concepts based on the knowledge, experience, and values of the problem-solver. Frames largely affect how to view, represent, and construct problems and solutions. Design is a field that deals with wicked problems, and due to their ambiguous and fuzzy nature are difficult to solve. In spite of its importance for design practice, current research on F-RF is fragmented and incomplete. How to measure F-RF empirically remains underexplored and unsystematic.

This project intends to investigate F-RF by using a newly developed quantitative method based on first occurrences of concepts that employs the FBS ontology for measuring F-RF. The project will explore its relationship with the quality of the design solutions. Small-scale qualitative research on expert designers has pointed to a potential relation between more F-RF and higher performing solutions. To gain a deeper insight the project will measure quantitatively F-RF behavior of design experts and novices and will correlate these with their solutions. Their F-RF behavior will be used to assess differences between design experts and novices.

To achieve these goals, a contrast experiment will be carried out with the independent variable being expertise. Expert architects and architecture students will be used as participants. Data will be obtained using think-aloud protocol analysis. Verbalizations of participants articulated while designing will be recorded and cognitively coded using the widely applied FBS coding scheme, which gives access to design cognition. The co-activations of first occurrences of concepts and their cognitive codes will be used to characterize a frame. The coded protocols will be also used to identify characteristics of F-RF at different stages of the design process. The quality of solutions will be assessed using the consensual assessment technique (CAT).

The study’s originality is that if offers a systematic approach to investigate design F-RF and its effects. The primary contribution is to determine the relationship between F-RF behavior and design solutions. It will lay the foundation for future interventions that improve innovation and related problem-solving. A further contribution is the introduction of a method to the design decision-making domain that allows the empirical and quantitative measurement of F-RF. Any design field is likely to benefit with this study, from those dealing with physical objects such as architecture and engineering, to those focusing on virtual objects such as software and gaming design, and the design of simulations. The knowledge generated by this project has the potential to produce long term improvements in the contribution of design to the national economic and social wellbeing.

**How does framing and reframing in design problem-solving affect the quality of solutions**

## Scientific Background [MAXIMUM 15 PAGES – EXCLUDING REFERENCES]

Design problems are described as wicked, complex, multifaceted (Rittel & Webber, 1984; Schön, 1985), and ill-defined (Simon, 1984). Designers must deal with manifold situations that are unique, fuzzy, and in conflict (Schön, 1983). From the earliest stages of the design process, designers have to define initial requirements and goals, clarify design intentions and ideas, and construct and develop problems that lead to solutions (Cross, 2011). Hence, understanding the design activity requires studying designing, particularly at the early stages of the process, also known as conceptual design.

Rittel and Webber (1984) stated that the setting of the design problem is the main and most challenging component of all design activities. Some of the reasons are because it is ambiguous, fuzzy, and necessarily incomplete. Schön (1983) referred to problem setting as naming and framing: “Problem setting is a process in which, interactively, we namethe things to which we will attend and framethe context in which we will attend to them.” Frames are defined as a set of grounded, co-activated concepts based on the knowledge, experience, and values of the problem-solver. The process of problem-setting or problem-framing helps to gain a global outlook about the design situation and the interaction between the elements that shape the design (Zahedi & Heaton, 2017). However, research into these ideas in the study of designing has been slow (Ylirisku, 2013). Cross (2007) argued that describing design as problem framing might best reflect the major aspects of the design activity, perceived as the process of structuring and formulating the problem. Although framing and reframing (F-RF) is a fundamental cognitive activity that takes place in all problem-solving fields including design, there is still an inadequate understanding of its contribution to constructing design problems and their solutions. Apart from some early studies (e.g., Cross, 2006; Lawson, 2006; Schon, 1987; 1995) there is not much empirical evidence in design research on how F-RF works. While framing is often related to expertise, it is also surprising that most research is based on design students.

Despite its importance for design practice, how to measure F-RF quantitatively remains largely underexplored. There is a need to measure this fundamental design activity systematically using a well-established ontology that will enable insight into the cognitive behavior of the designer during this foundational aspect of the design process. A lack of a systematic measure of F-RF prevents cross-comparisons and generalizations from findings from different studies. However, research on expertise focusing on design F-RF is underexplored. Objectively measuring and comparing F-RF behavior between experts and novices will contribute to gain further insight onto design thinking. A better understanding of what characterizes expert F-RF behavior can provide the foundation for improving design performance and productivity.

**I1 Framing and reframing behavior in design problem-solving**

**I1.1 Framing and frames**

Framing (F) has been investigated as a cognitive activity that is part of the design process, but this notion is not unique to design. F is a concept that has its origins in studies on the ecology of mind (Bateson, 1972), and in social sciences as a process through which societies reproduce meaning (Goffman, 1974). The idea of ‘frame’ was introduced in the artificial intelligence domain in reference to the adaptation of cognitive structures to match new conditions (Minsky, 1975). Since then, studies on F were carried out in a variety of fields such as urban planning, engineering, psychology, management sciences, and design. In spite of the attention devoted to it, definitions of what constitutes a frame continue to be scarce (Stumpf & McDonnell 2002). Bateson (1972) referred to F as a boundary-setting cognitive mechanism, enabling to make decisions about what actions or information are meaningful. The act of F was also considered to encompass values, beliefs, and differing perspectives (Judd et al., 1991). A comprehensive overview about different interpretations of F was made by Fisher (1997), who developed the theoretical case for defining frames as semi-structured elements of discourse that people employ to make sense of information they encounter. F was also considered in the context of problem-solving. The concept problem framing reflects how problems are presented, including the formulation of constraints, goals, and instructions for the task (Tversky & Kahneman, 1981). Problem framing is also seen as the process by which individuals consciously or unconsciously structure a situation by choosing relevant features. F provides structure from the perspective of the problem-solver, and enables to stress and hide different elements of the situation. Usually, F comprises assumptions of a desired outcome, and of what is acceptable or not (Hey, 2008). Modifying the scope of a problem can affect the types of solutions generated (Silk et al., 2021).

**I1.2 Framing and reframing in the design process**

At the outset of the design process, there may not be complete problems to start dealing with, but rather the problems have to be constructed, and this process can be best conceptualized in terms of problem framing.The skill to frame a challenging situation in novel and surprising ways is a fundamental feature of design thinking (Beckman, 2020). In design theory, the concept of frame is largely based on Schon’s (1984, 1987, 1995) work on reflective practice. In his view, frames are essential structures of belief, perception and appreciation. As a result of their experience and understanding, designers become progressively conscious to assess, and adapt the frames they use to direct their actions. Frames endow coherence to the design problem and allows designers to look at it as something known, what enables to treat the design situation using more familiar examples.

Schon’s (1983) analysis of the design activity incorporated framing as a critical ability, understood as a perception of a problematic situation, and a form of reasoning that enables the designer to develop an assortment of possible actions. Accordingly, design framing (F) is about defining the boundaries of the design problem, focusing on certain objects and relationships, and establishing some norms that might aid to guide subsequent design moves following a certain logic (Schön, 1995). F, however, is a subjective activity. Designers make individual value judgments to construct and develop their own views of the design situation. As the design progresses, initial design ideas are transformed and tested against conjectures, and new hypotheses about the design situation are formulated at the time that new frames are imposed. F develops sequentially, and while reflecting about the design, new issues, conflicts, and opportunities emerge. During this process, the initial frame serves as the basis of new frames. The designer continues to be observant of the situation’s back-talk, and is ready to re-frame (RF) it when he or she finds it convenient (Schon, 1983).

During the F-RF activity, problem goals, the experience and knowledge of the designer, including 'primary generators' (Darke, 1984), guiding principles, and schemata, (Lawson & Dorst, 2009) are brought together to inform how to initially pre-structure a situation (Dorst, 2006). RF implies the construction of new frames by reinterpreting and endowing new meaning to the understanding of the task and the design context (Paton & Dorst, 2011). RF is seen to occur as an outcome of reflecting about the changes that occurred on the design situation during the design process. This cognitive activity is considered crucial to not only help create alternative interpretations of conflicting situations, but also to redefine problem statements, goals, expectations, needs and to produce original and qualitative design outcomes. The work of Schon attracted much interest in design theory and research, influencing a broad number of studies that focused on F, and its evolution through the design process. There is recent interest in the notion of F as a means for analyzing and thinking about the design process, with a focus set on patterns or structures that characterizes design behavior in design processes (Adams et al., 2018; Dorst, 2015; Lloyd & Oak, 2018). While some of these works dealt with the F activity of the individual designer (e.g., Lee et al., 2020; Paton & Dorst, 2011), others focused on that at the team level (e.g., Stompff-Oce et al., 2016; Stumpf & McDonnell, 2002; Ylirisku, 2013). Dorst and Cross (2001) reported a set of protocol studies of designers working individually on a design assignment. They found that creative events take place as part of a co-evolution process in which a problem-solution pair is framed. Hey and Agogino (2008) demonstrated that design framing and the development of shared understanding of the task among team members are interwoven through the activities carried out in team. McDonnell (2018) showed that F can lead to design solutions valued for their innovation and effectiveness. Van der Bijl-Brouwer and Dorst (2017) proposed frame creation as a singular design method to support and provide meaningful value in strategic innovation.

**I1.3 Framing and design expertise**

Expertise is generally defined as an exceptional or superior performance of an individual in a domain (Ericsson, 2006). Increasing attention has been paid to understanding the nature and development of expert behaviour in design (Cash et al., 2017; Neroni & Crilly 2019). A main reason is because design problems are wicked, and framing (F) them demands some level of expertise (Smith, 2015). To gain insight into the problem context comprehensively, designers must use their experience and knowledge to interpret and frame the design situation adequately. A characteristic of such behavior is the engagement in active problem F instead of simply problem-solving (Crismond & Adams, 2012). In order to gain awareness about contextual constraints and specifications, they treat design problems more critically than novices (Ahmed et al., 2003). Expert designers question initial assumptions about a design problem, while novices generally assumes that a problem should be accepted as originally formulated and cannot be changed (Dorst, 2011; Harfield, 2007). Silk et al. (2021) found that while experts actively interrogate and F-RF problems at hand, novice designers tend to solve them as given. Therefore, they are more reluctant to consider alternative interpretations of the problem and proceed very fast to generate solutions. In contrast, experts spend time and effort in structuring, understanding, and gathering relevant information while generating design alternatives before deciding about the final solution (Atman et al., 2007; Cross, Christiaans, & Dorst 1996). This important capability of design expert behavior (Cross, 2004; Casakin & Levy, submitted; Lawson & Dorst, 2013) was found to be critical to achieve high-level performance in the design outcomes (Dorst & Cross, 2001; Paton & Dorst 2011).

**I2 Cognitive studies for measuring the design activity**

Studying design cognition is seen as a basic way of thinking and knowing supplemental to scientific and computational thinking (Cross, 2011; Kan & Gero, 2017; Kelly & Gero, 2021). This mode of thinking is said to reflect the vital aspects of the activities – e.g., F-RF that designers carry out throughout all design disciplines, including architecture and engineering (Lawson, 2006). Exploring design thinking from the design processes and recognizing the regularities in designing that go beyond any specifics of designers aids to reveal the essence of design thinking (Gero & Jiang, 2016). While gaining an understanding of the differences due to key characteristics of the designer such as expertise, confidence in these regularities can be enhanced further. This section presents the theoretical background of the methodologies that will be used in this project to explore F-RF design behavior. First the protocol analysis methodology is introduced, followed by the FBS-ontologically-based coding scheme and the quantitative measurements that can be carried out from the coded protocols.

**I2.1 Protocol analysis**

Cognitive studies fall into five main methodological categories that include: protocol analysis, input-output experiments, interviews, anthropological studies, and surveys. From these, protocol analysis is one the best and most used methodologies for studying design cognition (e.g., Adams & Siddiqui, 2015; Cross et al., 1996; Gero & McNeill, 1998; Jiang & Yen, 2009). Protocol analysis is a formal observational research method. A design protocol is a recording of the time path of designers’ behaviors that take place through the design activity, that is frequently captured in sketches, notes, or audio/image recordings (Akin, 1986; Gero & Jiang, 2016). It is a rigorous and well-developed methodology for acquiring qualitative data in the form of verbal reports of thought sequences, and converting it into quantitative data (Ericsson & Simon, 1993; Kan & Gero, 2017). Design protocols are a specific representation of qualitative data, which is transcribed, parsed and categorized, and finally analyzed (Purcell et al., 1996). To this aim, the development or adoption and implementation of a coding scheme is crucial in the design protocol analysis process. Due to its power for offering an in-depth study of the design process in any design field, protocol analysis has become the most frequently used experimental technique for exploring the design process (Atman et al., 2007).

Most design protocol studies centered on the cognitive processes related to designing (for a systematic review on protocol studies see Hay et al., 2017). From these, a few works were carried out to analyze cognitive processes behind F-RF in design (e.g., Chandrasekera & D’Souza, 2013). However, coding schemes in these protocol studies are developed ad-hoc for the specific needs of the case studies.This hampers the possibility of generalizing and cross-comparison of findings from different analyses, i. e., they are incommensurable (Gero, 2010). To deal with this shortcoming and allow the comparison between design F-RF and the designing process – a reasonably well-studied domain, this project adopts the FBS ontologically-based approach, which has been employed in different design situations and activities irrespectively of the specifics of design disciplines, tasks and expertise of the designers (Gero & Kannengiesser, 2014). Using this method will allow commensurability of the results of this project with previous protocol studies of designing processes.

**I2.2 FBS Ontology**

In this project, the ontologically-based protocol analysis methodology is guided by a general design ontology, the Function-Behavior-Structure (FBS) ontology (Gero, 1990; Gero & Kannengiesser, 2004; 2014). The two foundational papers describing the FBS ontology have received over 4,000 citations (Google Scholar). A brief summary of the FBS framework with its relation to design is presented. Gero’s FBS ontology was used in many cognitive studies (e.g., Gero, & Milovanovic, 2019; Sadeghi et al., 2017; Song, 2014) since it claims to describe the most important design processes, and the transitions between design issues are classified into eight design processes. The FBS ontology contains three fundamental ontological variables: Function, Behaviour and Structure. Function (F) describes the aims or purposes of the object (i.e., “what the object is for”). Behaviour (B) is defined by the object's attributes that can be derived (Bs), or can be expected (Be) from its structure (i.e., “what the object does”). Structure (S) represents components that the object consists of, and their relationships (i.e., “what the artifact consists of”). The model is completed by two additional variables: Requirements (R), which stems from outside the design, and Descriptions (D), concerned with the documentation of the design. Both R and D are expressible in F, B or S, and therefore they do not extend the ontology. The six ontological constructs are labeled “design issues” (Kan & Gero, 2017). The FBS ontology leads to eight design processes — formulation, analysis, evaluation, synthesis, and reformulation I, II, and III, represented as transitions between the ontological constructs. These processes are concerned with: a formulation that transform functions into expected behaviours; a synthesis, in which a proposed structure is intended to show the expected behaviour; an analysis of the structure gives rise to its resultant behaviour; an evaluation compares the expected behaviour and the behaviour resulting from the structure; and documentation, which produces the design description. Three types of reformulations are possible from the structure when new variables are considered in the design: reformulation of structure, reformulation of expected behaviour, and reformulation of function. Figure 1 shows the relationships among the eight transformation processes and the three basic classes of variables.

**Diagram

Description automatically generated**

Figure 1 The FBS ontology of processes and variables (Gero & Kannengiesser, 2004)

**II. Research Objectives and Expected Significance**

In design, a frame is characterized by the co-activation of first occurrences of concepts within the context of the design being processed. Framing (F) is based on the knowledge, experience, and values of a designer, which reflects how he or she views, represents, and construct problems and solutions. Reframing behavior (RF), which refers to changing the original frame, can occur through three different types: i) adding concepts related to previously existing ones; ii) subtracting concepts, and iii) adding new concepts that do not overlap with existing ones.

Whereas F-RF are terms commonly used in design literature (e.g., Beckman, 2020; Dorst, 2015), most related studies are mainly theoretical or use qualitative methods of analysis. There appears to be no adequate objective measurement of F-RF, for example by considering the co-activation of first occurrences of concepts. Moreover, the relationship between F-RF and the quality of the design solutions has not been measured. As an alternative to qualitative methods used to study F-RF, this project proposes measuring this fundamental cognitive activity quantitatively from empirical data. While the design cognitive structures, cognitive activity, and performance of experts and novices was found to differ (e.g., Atman et al., 2007; Kavakli & Gero, 2002), whether experts have either more or different F-RF behavior than novices, and whether the average size of frames in experts is larger than those of novices is unknown, and therefore these have yet to be explored and measured empirically.

*Consequently, this project aims to investigate F-RF in design problem-solving.*

The objectives of the research are:

(a) to measure F-RFs quantitatively as the co-activation of first occurrence of concepts generated in design sessions

(b) to measure the size and span of frames

(c) to measure the relationship between F-RFs and the quality of the design solutions

(d) to compare F-RFs of design experts and novices, and

(e) to compare the relationship of F-RFs of experts and novices with the quality of their design solutions.

The innovation of this proposed project is its empirical, quantitative measurement of F-RF. This is underexplored and unsystematic. Hence, the intellectual merit of this proposal is that it addresses an important gap in our knowledge about how to measure F-RF and its effects. An additional contribution is to determine the relationship between F-RF behavior and design solutions. It will lay the foundation for future interventions that improve innovation and related problem-solving, both in professional practice and education.

A further impact of the current research resides in that it proposes a method to the design decision-making domain that allows the empirical and quantitative measurement of F-RF. Measuring this fundamental design activity systematically will contribute to gain insight onto the cognitive behavior of the designer during the design process.

Any design field is likely to benefit with this study, from those dealing with physical objects such as architecture and engineering, to those focusing on virtual objects such as software and gaming design, and the design of simulations.

The knowledge generated by this project has the potential to produce long term improvements in the contribution of design to the national economic and social wellbeing.

**III. Detailed Description of the Proposed Research**

**Working Hypotheses**

We formulated the following research hypotheses:

H1: F-RFs can be measured through the co-activation of first occurrences of concepts

H2: The average size and span of frames in experts will be larger than those of novices

H3: An increase in F-RFs positively correlates with an increase quality of the design solutions

H4: Experts will have more and different F-RFs than novices

For a connection between the research objectives and the hypotheses see Table 1.

# Table 1: Research objectives and hypotheses

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Research objectives | | | | | |
| Research hypotheses |  | Obj. a | Obj. b | Obj. c | Obj. d | Obj. e |
| H1 | X |  |  |  |  |
| H2 |  | X |  |  |  |
| H3 |  |  | X |  | X |
| H4 |  |  |  | X |  |

**Research Design and Methods**

The research design is a contrast experiment. The independent variable is expertise with two levels: experts and novices. The dependent variables are framing and reframing, and quality of design solutions.A graphical outline of the research plan is presented in Figures 2 and 3.

*Subjects*: Thirty architectural designers will participate in the experiments conducted in this study. They will be drawn from a convenience sample representing two groups with different levels of expertise. Purposeful selection will be used in assigning participants to experiment and control groups. The expert group will consist of 15 experienced designers - all architects with 10 to 15 years of experience in professional practice, working in a medium or medium-large size office in Israel. They will range in age from 35 to 40. The novice (control) group will consist of another 15 advanced architecture students from the School of Architecture at Ariel University, in their third and fourth year of undergraduate studies. They will range in age from 23 to 26, and about half of them will be women as well. The selection criteria for students will include that they be in the upper half performance. All participants including architects and students will be native Hebrew speakers.

*Procedure and setting*: Experiments will be carried out individually, in a lab-setting. They will last for 45 minutes. All participants will be given a design problem and a task sheet containing general instructions. They will be required to sketch while they generate as many ideas as possible to solvethe design problem provided. Participants will be given 3 minutes to read the problem and the general instructions. Thereafter, they will be asked to think aloud as the session will be recorded, and the camera will capture the sketches made by the subject. The experimenter will respond to any question, but will not intervene during the session, except to remind subjects toverbalize their thoughts if they were silent for longer than a few seconds, and to produce as many ideas as possible.Fifteen minutes prior to the end of the session, participants will be requested to produce a final solution. At the end of the experiment, a debriefing session will take place lastingabout 15 minutes. They will be asked to explain how comfortable they felt with the design task, how hard it was for them, to what extent they believe they have achieved their goals, how satisfied they are with the quality of their design solution, and how creative they believe it was.

*Design task*: A previously used task to be presented to participants will consist of designing a solution for a small museum located in a contentious area characterized by historical buildings (Casakin & Kreitler, 2011).

|  |  |  |  |
| --- | --- | --- | --- |
| **Protocol data analysis, and solution assessment**  **Protocol and solutions collection**   * design task * Videos * Design solutions   **Protocol coding**   * segment and code   **Experts working individually in design sessions**  **Characterize novice and expert F-RF**   * F-RF as co-activation of first occurrence concepts through the design process * Relationship between F-RF and quality of design solutions   **Multidimensional statistical models of novice and expert F-RF behavior**   * Framing * Reframing * Performance: solution assessment   **Model comparison**  **Novices working individually in design sessions**  **Protocol and solutions collection**   * design task * Videos * Design solutions   **Protocol coding**   * segment and code   **Protocol data analysis, and solution assessment**  **INPUTS**  **PROCESS**  **ANALYSIS**  **OUTPUTS** |  |  |  |

*Figure 2 Research plan*

**Multidimensional models of novice and expert F-RF behavior**

* Frequencies of FBS issues and processes
* 1st occurrence concepts and framing (F)
* Co-activation of 1st occurrence concepts and F-RF Correspondence analysis of F-RF and FBS issues
* Correspondence analysis of F-RF and FBS processes
* Correspondence analysis of F-RF and P-S
* Temporal distribution of F-RF
* P-S interaction and F-RF issues
* FBS interactions and F-RF
* P-S coevolution and F-RF issues
* FBS coevolution and F-RF
* Cumulative occurrence of FBS issues and processes and F-RF
* Relation between F-RF and quality of design solutions

*Figure 3 Multidimensional models of novice and expert design framing and reframing*

***Data collection and analysis***

The data collection and analysis procedures are detailed in Table 2. In phase 1, the 30 design sessions recorded in the first stage of the study will serve to collect data using think-aloud protocol analysis.

In phases 2 & 3, the transcripts containing the recorded verbalizations of participants articulated while designing will be segmented, cognitively coded, and analyzed using the FR-F, FBS, and P-

# Table 2: Project phases, tasks, and timelines



S coding schemes. Multiple statistical analysis techniques will be employed to obtain models from

the data sets, which will be used to address the objectives and test the research hypotheses (For a connection between the hypotheses and the statistical models see Table 3). The statistical techniques together with the models and the coding schemes are presented as follows.

*FBS coding:* Verbalizations of participants will be coded using the widely applied FBS coding scheme, which as noted before gives access to design cognition. The FBS codes represent the cognitive activations of the design issues that the designers are thinking about while they design. The first occurrences of concepts and their cognitive codes will be used to characterize a frame.

The following measurements and analysis methods will be employed on the basis of FBS-based segmented and coded protocols (Pourmohamadi & Gero, 2011):

i) Frequencies of FBS design issues and processes. They will be analyzed for significant differences due to expertise )i.e., FBS codes X Expertise). Thereafter, correspondence analysis will be applied to visualize and explore latent patterns in the categories of the data (Greenacre, 2007).

ii) F-RF. To test H4, the coding scheme will be augmented by a further code used to tag Framing and Reframing segments. To this aim, transcripts segmented and coded using the FBS design issues codes will undergo a second pass of coding for segments containing first occurrences of concepts concerned with design F-RF. Accordingly, F-RFs will be analyzed independently for design function, behavior, and structure (i.e., F-RF codes x FBS issues). F-RFs will be also analyzed independently for the eight FBS design processes (i.e., F-RF codes x FBS processes). Thereafter, F-RFs will be analyzed for significant differences due to expertise )i.e., F-RF codes X Expertise). A correspondence analysis will be then used to explore latent patterns in the categories of the data.

iii) First occurrences of concepts and frames. An aspect of the problem or solution that is introduced for the first time is defined as first occurrence of a concept in that design. This offers an objective and repeatable measure of design change. First occurrence of a concept is important since as a unique component in a frame, reflects a shift in the cognitive focus of the designer. To test H1, an algorithm will be used to identify first occurrence of concepts in a frame, and then count them along the design process (Lu, 2021).

iv) Concept co-activation and F-RF. Frames can be characterized by the co-activation of concepts, either existing or new ones. Frames can be unique or superpose partially or completely with other previous frames. Unique frames, where at least one of the related concepts is new, can be characterized by the co-activation of a first occurrence concept with other existing concepts.. In order to test H1, we will identify and explore the relations of the co-activated concepts in the different frames generated during the design process. To this aim, k-means clustering statistical technique (e.g., [Kaufman &](https://onlinelibrary.wiley.com/action/doSearch?ContribAuthorStored=Kaufman%2C+Leonard)[Rousseeuw](https://onlinelibrary.wiley.com/action/doSearch?ContribAuthorStored=Rousseeuw%2C+Peter+J), 2005) will be used as a method to characterize a frame by analyzing the co-activated concepts and their relationships.

v) Semantic distance of concepts and F-RF. A frame can be measured in relation to its span by calculating the semantic distance between its co-activated concepts. Semantic distance is a natural language processing measure referring to words and their meanings in a mathematical space (Fauconnier et al., 2003). This notion was used to analyze design concepts generated in problem solving activities (Casakin & Georgiev, 2021; Cash et al., 2014). To test H2, the span of the different frames will be measured by representing them in a concept map (Add reference), and the results of novices and experts will be compared.

vi) The problem-solution (P-S) index, which measures the cognitive focus set on either the design problem or the design solution (Jiang et al., 2014), will be calculated to test H1. It categorizes the FBS coded design issues into problem-related issues (requirement, function and expected behavior) and solution-related issues (behavior from structure, and structure) hinging on a classification of reasoning about the design problem and the design solution. The index is then calculated as the ratio of the summed frequency of problem-related issues over the summed frequency of solution-related issues. A P-S index value of greater than 1 means that the designer is more focused on reasoning about design problem than the design solution. A P-S index of less than 1 shows that the designer has spent more cognitive effort on reasoning about design solutions than about the design problem. F-RF, measured through the co-activation of first occurrences of concepts, will be analyzed to explore whether it focuses primarily on the problem or on the solutions. To this aim, segments using F-RF code will go through another pass of coding for problem-related issues (P) and solution-related issues (S). F-RFs will be analyzed for significant differences due to problem and solution spaces )i.e., F-RF codes X P-S). A correspondence analysis will be then carried out to explore latent patterns in the categories of the data. Thereafter, to test H4 the P-S behavior of novices and experts will be compared.

vii)Design co-evolution analysis.The reflective conversation of the designer with the design situation can be characterized as a co-evolution between different design issues. For example, co-evolution can take place between the design problem and the potential solution spaces (Dorst & Cross, 2001; Maher & Poon, 1996). Using F-RF coding, the cognitive activity of the designers can be analyzed while they move through these spaces, meaning how F-RF activity in one design space influences the F-RF activity in another space. Analyzing the design activity through F-RF offers a systematic way in which designers’ verbalizations can be mapped into the problem and solution spaces through the design process. To test H1, the F-RF activity of the designers will be characterized as a series of transitions in a two-dimensional space characterized by movements or influences in the problem-solution continuum (i.e., F-RF X P-S co-evolution). Additionally, a similar analysis will be carried to gain further insight into the cognitive activity of the designers characterized by the co-evolution between F-RF and the FBS ontology (i.e., F-RF X FBS co-evolution). Accordingly, F-RFs will be characterized as a series of transitions in a two-dimensional space characterized by movements in the design function, behavior, and structure spaces. A correspondence analysis will be then used to explore latent patterns in the categories of the data. The co-evolution each of the categories presented above will be measured based on the first occurrences of concepts in F-RF (Gero, et al., unpublished). Then, to test H4 the co-evolution of F-RFs characterized in the FBS and P-S spaces will be analyzed for significant differences due to expertise.

viii) Cumulative occurrence of F-RF. To test H1, the cumulative occurrence of F-RF will be calculated as a summed of the occurrence of F-RF from the beginning of a protocol (first occurrence) to the current segment. The cumulative occurrence of F-RFs is a measure of the time distribution of cognitive effort across a design session as compared to just the design distributions, which have no time dimension. It measures the rate at which participants’ have espended cognitive effort on the design session. The cumulative occurrence (C) of F-RF (x) at segment (n) is Cx = ni =1 xi, where (xi) equals 1 if segment (i) is coded as (x), and 0 if segment (i) is not coded as (x). Plotting the results of this equation on a graph with the segments (n) on the horizontal axis and the cumulative occurrence (C) on the vertical axis produces a visualization of the cumulative occurrence of the F-RFs (Sakao et al., 2001). Thereafter, to test H4 the cumulative occurrence of F-RFs will be analyzed for significant differences due to expertise.

ix) Quality of design solutions. The quality of the solutions produced by the designers will be assessed using the Consensual Assessment Technique (CAT) (Amabile, 1982). The CAT approaches assessment of outcomes through the subjective evaluation by expert judges with at least 10 years of design experience. To test H3, correlation analyses between the quality of design solutions and the different measurements of F-RF will be carried out.

All the above measures will be independent of the length of the design sessions. This enables the comparison of design protocols with different numbers of segments.

# Table 3: Research hypotheses and measurements

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Research hypotheses | | | | |
| Measurements |  | H1 | H2 | H3 | H4 |
| Mi | --- | --- | --- | --- |
| Mii |  |  |  | X |
| Miii | X |  |  |  |
| Miv | X | X |  |  |
| Mv |  | X |  |  |
| Mvi | X |  |  | X |
| Mvii | X |  |  | X |
| Mviii | X |  |  | X |
| Mix |  |  | X |  |

*Coders and coding reliability*: Two independent coders will simultaneously segment and code the transcripts, repeatedly dividing an utterance until each individual segment will contain a single code reflecting only one of the six possible FBS design issues. A further code will reflect F-RF behavior defined by first occurrences of concepts. After the independent segmentation and coding of a transcript, coders will arbitrate to produce a final coding. Where arbitration does not result in an agreement, a third, more experienced coder will be used. Inter-coding reliability will be measured by comparing each coder’s coding against the arbitrated code conveyed as a percentage agreement. Cohen’s kappa will be used to measure the inter-coder reliability (Cohen, 1988). An acceptable coding reliability against the final codes should be above 80% (Williams et al., 2011). The resulting arbitrations from the final protocol data sets that will be used in the statistical analyses. Final protocols for a 45-minute design session typically prompted between 400 and 1200 individually coded segments. With six codes, each code is expected to occur on average 125 times in each design session, which represents sufficient data for statistical analysis.

The above measurements and statistical models obtained from the data sets will help to find frames, explore different aspects of frames, and investigate their relationship with the quality of design solutions. A frame is independent from the categories it derives. Consequently, the proposed measures will enable to identify whether a frame is located in one design category/space (e.g., the solution space; the function space), or in multiple design categories/spaces (e.g., across problem and solution spaces; across function, structure, and behavior from structure spaces). Eventually, although beyond the scope of the present proposal, characterizing frames can be used to investigate teams of decision makers, and determine which team member contributes to what area. Analyzing F-RF quantitatively will enable to gain insight into the relationship between frames and the different design spaces where designers – novices and experts - are putting their cognitive effort to view, represent and construct problems and solutions during the design process.

## Preliminary Results [about two pages]

## To be completed, mainly to show that the methodology to be used in this project was partially used before based on an ongoing research leaded by H. S.

## Existing Research Conditions

The PI has published research papers in the fields of design thinking and design cognition, and in related areas such as design expertise, and the design studio. The PI has extensive experience with quantitative and qualitative research methods, including protocol analysis and the use of coding schemes.

The PI has committed two RAs who are available for the current research project. The current research is guided and supported by Prof. John Gero, who is an outstanding / eminent international research authority in the design field (See enclosed support letter). He has many publications in leading journals related to the main topics of the present research proposal. Professor Gero’s design research publications have 26,000 citations. An external consultant will be employed for carrying out the required statistical calculations.

The experiment will take place in a lab-setting located at the School of Architecture, Ariel University. It is a well ventilated and noise isolated room, with adequate furniture for carrying out design sessions.

**Expected Results, Possible Pitfalls and Remedies**

The development of the proposed models will be based on established theories and literature, an exploratory study concerned with design sessions, and established empirical methods that will be used in combination for the first time to study and measure F-RF behavior in design. Therefore, it is expected that the results will consolidate and expand existing knowledge about F-RF and will serve to propose further working hypotheses for future research.

After the independent segmentation and coding of the transcripts, coders will arbitrate a final coding with a third coder. Inter-coding reliability will be measured by comparing each of the coder’s coding against the arbitrated code conveyed as a percentage agreement. However, if the inter-coder reliability will be low, further tutoring will be provided to the coders to improve their reliability.

Another issue is concerned with difficulties in finding good co-activation of design concepts related to the framing activity. Co-activation is related to the clustering of concepts, If the co-activation clustering does not produce the expected results, we will control the clustering parameters affecting the connectivity among concepts. The way that we will deal with this would be to change the threshold for clusters for co-activation until a suitable cluster will be found.

There is a plan to recruit senior architects as participants from leading architectural offices in Israel. However, finding and receiving the consent of senior architects to participate in our study might be a challenge. Hence, personal contacts at the Association of Architects will be used to reach consent. If this recruitment proves to be difficult, assistance of colleagues from the university will be seek. If all the above shows to be unsuccessful, there is a plan to use a professional manpower company to contact potential participants from chief architectural firms.

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## Time schedule and work-plan

|  |  |  |
| --- | --- | --- |
| **Activity** | **Beginning** | **End** |
| Design sessions and protocol collections from novices | October 2022 | June 2023 |
| Design sessions and protocol collections from experts | October 2022 | June 2023 |
| Tutoring and training research assistants in coding | October 2022 | December 2022 |
| Transcriptions from novice sessions: segmentation and coding by two independent coders | November 2022 | November 2023 |
| Transcriptions from expert sessions: segmentation and coding by two independent coders | November 2022 | November 2023 |
| Assessment of students' design solutions by three independent referees | July 2023 | September 2023 |
| Assessment of architects' design solutions by three independent referees | July 2023 | September 2023 |
| Characterization of novices’ coded protocols as statistical models | October 2023 | June 2024 |
| Characterization of experts’ coded protocols as statistical models | January 2024 | June 2024 |
| Framing characterization of novices’ protocols as statistical models | April 2024 | December 2024 |
| Framing characterization of experts’ protocols as statistical models | April 2024 | December 2024 |
| Comparison of novices’ and experts’ results | October 2024 | June 2025 |
| Dissemination of preliminary results to design and related problem-solving communities | October 2023 | September 2024 |
| Dissemination of final results to design and related problem-solving communities | October 2024 | September 2025 |

**Personnel**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name (last, first) | Role in project | % time devoted | Salaries (in NIS) | | |
| 1st year | 2nd year | 3rd year |
| Hernan Casakin | PI | 20 | 0 | 0 | 0 |
| Graduate student 1 | RA | 100 | 72,000 | 72,000 | 72,000 |
| Graduate student 2 | RA | 50 | 36,000 | 36,000 | 0 |
| **Total Personnel** |  |  | **108,000** | **108,000** | **72,000** |

**Justification for requested Personnel:**

Two research assistants (RAs) will be employed in the project. The team will comprise two graduate students. Following comprehensive training that includes general instructions on research procedures and specific guidance on coding and analysis of design protocols, the RAs will be qualified for administering the study and processing the data. At the beginning, RA assignments will involve recruiting participants (students and architects) for taking part in the design sessions, and acting as experimenters during the design sessions. At any given time, the PI will oversee RA work, and RAs will report routinely to the PI. Weekly update meetings will be conducted during data collection and data analysis. Upon completion of the experiment, the RAs will collaborate in transforming the verbalizations of the students’ and architects’ design sessions into transcripts, in segmenting the transcripts, in protocol analysis using the coding, as well as in the cognitive characterization of the transcripts as statistical models. The RA1 will work 100% of the time during 3 years, at the rate of NIS 6000 per month (NIS 216,000), and the RA2 will work 50% of the time during 2 years, at the rate of NIS 3000 per month (NIS 72,000). A total of NIS 288,000 is therefore projected for the duration of the proposed research project (three years).

**Supplies & Materials**

|  |  |  |  |
| --- | --- | --- | --- |
| Item | Requested sums (in NIS) | | |
| 1st year | 2nd year | 3rd year |
| **Total Supplies & Materials** | **0** | **0** | **0** |

**Justification for requested Supplies & Materials:** Snacks & drinks for participants?

**Services**

|  |  |  |  |
| --- | --- | --- | --- |
| Item | Requested sums (in NIS) | | |
| 1st year | 2nd year | 3rd year |
| Design sessions | 5,250 | 0 | 0 |
| Assessment of final solutions | 2,400 | 0 | 0 |
| Consultant -Statistical analysis | 0 | 0 | 12,000 |
| Manpower Company | xxxxxxxxxxx |  |  |
| **Total Services** | **7,650** |  | **12,000** |

**Justification for requested Services:**

1. Fifteen students will be paid the sum of NIS 50 each for participating in the design session (about 1 hour), NIS 750 in total. Fifteen architects will be paid the sum of NIS 300 each for participating in the design session at the School of Architecture, Ariel University (about 1 hour), NIS 4,500 in total. The required number of participants is 30 (15 from each group). The total cost is NIS 5,250.
2. External referees will be paid the sum of NIS 100 (about 8 hours in total) for assessing the design outcomes produced by the participants during the design sessions. The required number of referees is 3. The total cost is NIS 2,400.
3. The data collected in the design sessions will be coded. The outcomes of these will be submitted to a consultant /statistician, who will process this data through statistical tests. The estimated number of hours for this task is 40 hours, each at the rate of NIS 300 per hour. The total cost is NIS 12,000.
4. Eventually, the services of a Manpower Company might be requested to recruit architects to participate in the experiments. The total cost is NIS xxxx

.

**Computers**

|  |  |  |  |
| --- | --- | --- | --- |
| Item | Requested sums (in NIS) | | |
| 1st year | 2nd year | 3rd year |
| Personal computer for the researcher | 0 | 0 | 0 |
| Personal computer (laptop) for students/research assistants | 5,000 | 0 | 0 |
| Windows software operation system license | 1,000 | 0 | 0 |
| Peripherals (camcorder) | 1,700 | 0 | 0 |
| Peripherals (tripod) | 500 | 0 | 0 |
| Peripherals (micro SD 128gb) | 150 | 0 | 0 |
| External microphone | 300 | 0 | 0 |
| Cloud computing |  |  |  |
| **Total Computers** | **8,650** | **0** | **0** |

**Justification for requested Computers:**

1. One personal computer is required for operation. This will cost NIS. 5,000
2. Windows software operation system license will be purchased at the cost of NIS 1,000.
3. A camcorder for recording the design sessions. This will cost NIS 1700
4. A tripod for holding the camcorder. This will cost NIS 500
5. Micro SD will be used to record the design sessions for about 30 hours. This will cost NIS 150

**Miscellaneous**

|  |  |  |  |
| --- | --- | --- | --- |
| Item | Requested sums (in NIS) | | |
| 1st year | 2nd year | 3rd year |
| Internet Connection (office/lab only) | 0 | 0 | 0 |
| Photocopies and office supplies | 500 | 500 | 500 |
| Memberships in scientific associations | 500 | 500 | 500 |
| Publication charges in scientific journals (including editing and translation) | 7,500 | 7,500 | 7,500 |
| Professional literature | 0 | 0 | 0 |
| **Total Miscellaneous** | **8,500** | **8,500** | **8,500** |

**Justification for requested Miscellaneous:**

Other expenses, requested to create a proper and facilitative research environment, include office supplies, photocopies and printouts, computer supplies, publication charges in scientific journals, professional literature, and memberships in scientific associations. Total miscellaneous costs are NIS 18,000.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Requested sums (in NIS) | | |
| 108,000 | 108,000 | 72,000 |
| Personnel | 0 | 0 | 0 |
| Supplies & Materials | ? | ? | ? |
| Services | 7,650 | 0 | 12,000 |
| Other Expenses | 8,650 |  |  |
| Computers | 0 | 0 | 0 |
| Miscellaneous | 8,500 | 8,500 | 8,500 |
| Infrastructure In Other Universities | 0 | 0 | 0 |
| Overhead | 22,576 | 19,805 | 15,725 |
| Equipment (no overhead on this item) | 0 | 0 | 0 |
| **Total budget** | **155,376.00** | **136,305.00** | **108,225** |
| **Annual average** | **133,302.00** | **133,302.00** | **133,302.00** |
| International Cooperation (including overhead) | 0 | 0 | 0 |
| Infrastructure In Other Universities | 0 | 0 | 0 |

## Curriculum Vitae

**Name: Hernan Casakin**

1. **Academic Background**

|  |  |  |  |
| --- | --- | --- | --- |
| Date (from-to) | Institute | Degree | Area of specialization |
| 1999-2000 | Hamburg University | Postdoctoral studies | Architecture, design and cognitive psychology |
| 1993-1998 | Technion- Israel Institute of Technology | D.Sc | Architecture, design and cognition |
| 1990-1993 | Technion- Israel Institute of Technology | M.Sc | Architecture, design and computation |
| 1984-1989 | National University of Mar del Plata | B.A | Architecture and Urban Planning |

1. **Previous Employment**

|  |  |  |  |
| --- | --- | --- | --- |
| Date (from-to) | Institute | Title | Research area |
| 2015-Present | Ariel University | Assoc. Professor | Architecture and Design thinking |
| 2009-2015 | Ariel University | Senior Lecturer | Architecture, and Design thinking |
| 2006-2009 | Tel Aviv University | Lecturer | Architecture and Environmental psychology |
| 2001-2005 | Tel Aviv University | Research Fellow | Design, Cognition and the Environment |
| 1998-2009 | Ariel University | Lecturer | Architecture and Design thinking |
| 1999-2005 | The College of Management | Lecturer | Architecture and Design |

1. **Grants and Awards Received Within The Past Five Years**

|  |  |  |  |
| --- | --- | --- | --- |
| Date (from-to) | Institute | Title | Research area |
|  |  | Reviewer excellence?  Internal Grants? |  |

PI1 Name: Assoc. Prof. Hernan Casakin

# LIST OF PUBLICATIONS

**Hernan Casakin**