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**Personal Research Grants**

**Research Grant Application no. 798/22**

## General application information

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

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

involvement in social commerce: The struggle between barriers and motivation

**Keywords**

Frame; framing, reframing, design thinking, problem-solving, expertise, protocol analysis, FBS, first occurrence of concepts

**Requested Budget in NIS**

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Date

Application No. 798/22

PI1 Name: Hernan Casakin

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

Framing and reframing (*F-RF*), a fundamental cognitive activity that occurs across all problem-solving fields, has been studied qualitatively in design and innovation. Frames are a set of grounded, coactivated concepts based on the knowledge, experience, and values of the problem-solver and largely affect how to view, represent, and construct problems and solutions. The field of design often deals with wicked problems, which, due to their ambiguous and fuzzy nature, are difficult to solve. Despite *F-RF*’s importance for design practice, current research on the subject is fragmented and incomplete, and methods for measuring *F-RF* empirically remains underexplored and unsystematic.

This project investigates *F-RF*, exploring its relationship with the quality of the design solutions, applying a newly developed quantitative method, based on first occurrences of concepts, which employs the Function-Behavior-Structure (*FBS*) ontology for measuring *F-RF*. Small-scale qualitative research on expert designers has suggested a potential relationship between more *F-RF* and more effective solutions. To gain a deeper insight into this question, the project will quantitatively measure and compare the *F-RF* behavior of design experts and novices and will correlate the results with the quality of their solutions.

To this end, we will use a contrast experiment with level of expertise as the independent variable, studying participants from a group of expert architects and a group of architecture students. The think-aloud protocol analysis methodology, whereby participants vocalize their thinking and problem-solving process while we record their verbalizations and code them cognitively using the widely applied *FBS* coding scheme that identifies design cognition, will be used to conduct the study and collect data. The coactivations of first occurrences of concepts and their cognitive codes will be used to characterize a frame. The coded protocols will be 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 lies in offering a systematic approach to investigating design *F-RF* and its effects. Its primary contribution is the exploration of the relationship between *F-RF* behavior and design solutions, thereby laying the foundation for future interventions to improve innovation and related problem-solving. A further contribution is the introduction of a method to the design decision-making domain that facilitates the empirical and quantitative measurement of *F-RF*, which can benefit any design field, from those dealing with physical objects, such as architecture and engineering, to those focusing on virtual objects, such as software, gaming, and simulation design. 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 well-being.

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

**I. Scientific Background**

Design problems are described as wicked, complex, multifaceted (Rittel & Webber, 1984; Schön, 1985), and ill-defined (Simon, 1984). Designers must cope with multi-faceted situations that are unique, fuzzy, and in conflict (Schön, 1983). From the earliest stages of the design process, designers must 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 the process, particularly at its early stages, also known as conceptual design.

Rittel and Webber (1984) consider the setting of the design problem as the primary and most challenging component of all design activities because it is ambiguous, fuzzy, and necessarily incomplete. Schön (1983) defined problem setting as a process of 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, coactivated concepts based on the knowledge, experience, and values of the problem-solver. The process of problem setting or problem framing helps in attaining a comprehensive view of the design situation and the interaction between the elements shaping the design (Zahedi & Heaton, 2017). However, more research into the application of these ideas in the study of design is needed. Cross (2007) argued that describing design as problem framing might best reflect the major attributes 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 occurs in all problem-solving fields, including design, understanding its contribution to constructing design problems and their solutions remains inadequate. Apart from some early studies (e.g., Cross, 2007; Lawson, 2006; Schon, 1987; 1995), there is little empirical evidence in design research on how *F-RF* works. In addition, while framing is often related to expertise, most research nonetheless focuses on inexperienced design students.

Despite its importance in design practice, the methodology for measuring *F-RF* quantitatively remains largely underexplored. This fundamental design activity needs to be systematically examined using a well-established ontology that will provide insight into the cognitive behavior of the designer during this foundational stage of the design process. Lack of a systematic measure of *F-RF* prevents cross-comparisons and generalizations from findings of different studies, a lacuna compounded by the fact that the research into *F-RF* focusing on expertise is underexplored. Objectively measuring and comparing *F-RF* behavior between experts and novices will lead to further insights into design thinking. A better understanding of the characteristics of expert *F-RF* behavior can provide the foundation for improving design performance and productivity.

**I.1 Framing and reframing behavior in design problem-solving**

**I.1.1 Framing and frames**

While framing has been investigated as a cognitive activity that is part of the design process, this notion is not confined to design. Framing is a concept with 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 meet new conditions (Minsky, 1975). Since then, studies on framing have been carried out in a variety of fields, such as urban planning, engineering, psychology, management sciences, and design. Despite the attention devoted to it, definitions of what constitutes a frame remain scarce (Stumpf & McDonnell 2002). Bateson (1972) referred to framing as a boundary-setting cognitive mechanism, enabling decisions to be made about what actions or information are meaningful. The act of framing is also considered as encompassing values, beliefs, and differing perspectives (Judd et al., 1991).

A comprehensive overview about different interpretations of framing was made by Fisher (1997), who developed the theoretical case for defining frames as semi-structured elements of discourse people employ to make sense of information to which they are exposed. Framing has also been considered in the context of problem-solving. The concept of 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, allowing the designer to emphasize or conceal different elements of the situation. Usually, framing comprises assumptions of a desired outcome and of what is or is not acceptable (Hey, 2008). Modifying the scope of a problem can affect the nature of the solutions generated (Silk et al., 2021).

**I.1.2 Framing and reframing in the design process**

At the outset of the design process, when the initial problems may not be clearly or completely defined, the problems must start being constructed; 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 based largely on Schon’s work on reflective practice (1984, 1987, 1995). In his view, frames are essential structures of belief, perception, and appreciation. As a result of their experience and understanding, designers become progressively more conscious of frames, and thus more equipped to assess and adapt the frames they use to better focus their efforts. Frames imbue the design problem with coherence, providing a more familiar reference point from which designers can build on their extensive experience.

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 a variety of possible actions. Accordingly, design framing defines the boundaries of the problem, focusing on specific objects and relationships, and establishing norms to guide subsequent logical design decisions (Schön, 1995). Framing, is nonetheless a subjective activity, as designers make individual value judgments, constructing and developing their personal evaluations 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. Framing develops sequentially, with new issues, conflicts, and opportunities emerging during the course of reflecting about the design. In the course of this process, the initial frame serves as the basis of new frames. The designer continues observe the situation’s reactions and is prepared to reframe (*RF*) as needed (Schon, 1983). Through their reflective conversations with the design situation, designers frame and reframe problems (*F-RF*). The designers’ efforts to construct a solution leads to new discoveries, and consequently to more reflection about the new design situation (Visser, 2010).

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 provide designers the means to pre-structure a situation (Dorst, 2006). *RF* implies the construction of new or modified frames by reinterpreting the task and conferring new meaning on the understanding of it and of the design context (Paton & Dorst, 2011). RF occurs as a reflection of the changes the designer makes during this process. This cognitive activity is considered crucial not only for helping to create alternative interpretations of conflicting situations, but also for redefining problem statements, goals, expectations, and needs, thereby producing original and qualitative design outcomes. The work of Schon attracted much interest in design theory and research, influencing a wide range of studies focusing on framing and its evolution throughout the design process. There is recent interest in the notion of framing as a means for analyzing and thinking about the design process, examining, in particular, patterns or structures that characterize design behavior (Adams et al., 2018; Dorst, 2015; Lloyd & Oak, 2018).

While some of these works deal with the framing activity of the individual designer (e.g., Lee et al., 2020; Paton & Dorst, 2011), others focus on design done by teams (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, finding that creative events take place as part of a co-evolutionary 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 integrated throughout the activities carried out in team. McDonnell (2018) showed that framing 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.

**I.1.3 Framing and design expertise**

Expertise is generally defined as 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 behavior in design (Casakin & Levy, 2020; Cash et al., 2017; Neroni & Crilly 2019) because design problems are wicked, and framing them demands some level of expertise (Smith, 2015). To gain comprehensive insight into the problem context, designers must use their experience and knowledge to adequately interpret and frame the design situation, a process characterized by engagement in active problem framing rather than simply problem-solving (Crismond & Adams, 2012). To better clarify contextual constraints and specifications, experts examine design problems more critically than do novices (Ahmed et al., 2003). Expert designers question initial assumptions about a design problem, while novices generally assume 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 analyze and frame and reframe (*F-RF*) problems, novice designers tend to accept them at their face value and to be more reluctant to consider alternative interpretations of the problem, thus quickly generating immediate solutions. In contrast, experts spend time and effort in structuring, understanding, and gathering relevant information, while generating design alternatives before deciding on an optimal solution (Atman et al., 2007; Cross, Christiaans, & Dorst, 1996). This important capability of design experts(Cross, 2004; Casakin & Levy, submitted; Lawson & Dorst, 2009) was found to be critical in achieving high-level performance in design outcomes (Dorst & Cross, 2001; Paton & Dorst, 2011). Koronis et al. (2021), who explored the influence of the information contained in design briefs on the creativity of idea solutions, found that novices benefited from guidelines about how to *F-RF* design problems.

**I.2 Cognitive studies for measuring the design activity**

Design cognition is considered a basic way of thinking and knowing, supplementing scientific and computational thinking (Cross, 2011; Kan & Gero, 2017; Kelly & Gero, 2021). This mode of thinking reflects vital aspects of the activities, such as framing and reframing (*F-RF*) that designers carry out in all design disciplines, including architecture and engineering (Lawson, 2006). Exploring design processes and recognizing the regularities across all design fields can help elucidate the essence of design thinking (Gero & Jiang, 2016). While gaining an understanding of the differences attributable to key characteristics of the designer, such as expertise, confidence in these similarities can be further enhanced. This section presents the theoretical background of the methodologies that will be used in this project to explore *F-RF* design behavior. The protocol analysis methodology is first introduced, followed by the *FBS* ontologically-based coding scheme and the quantitative measurements that can be determined from the coded protocols.

**I.2.1 Protocol analysis**

Cognitive studies fall into five main methodological categories: protocol analysis, input-output experiments, interviews, anthropological studies, and surveys. From among these, protocol analysis, a formal observational research method, is one of the most effective and frequently used methodologies for studying design cognition (e.g., Adams & Siddiqui, 2015; Cross et al., 1996; Gero & McNeill, 1998; Jiang & Yen, 2009). A design protocol is a recording of the time path of designers’ behaviors that occur throughout the design activity, which can be 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 can be transcribed, parsed, categorized, and, finally, analyzed (Purcell et al., 1996). To this end, 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 have focused on the cognitive processes related to designing (for a systematic review on protocol studies see Hay et al., 2017). Drawing on these, some research has been carried out to analyze cognitive processes behind *F-RF* in design (e.g., Chandrasekera & D’Souza, 2013). However, coding schemes in these protocol studies have been developed ad hoc for the specific needs of the case studies, which impedes the possibility of generalizing and cross-comparing findings from different analyses, i. e., they are incommensurate (Gero, 2010). To overcome this shortcoming and enable a comparison between design *F-RF* and the designing process, a reasonably well-research area of study, this project adopts the *FBS* ontologically-based approach, which has been employed in different design situations and activities irrespective of the specifics of design disciplines, tasks, and expertise of the designers (Gero & Kannengiesser, 2014). Using this method will faciliatate commensurability of the results of this project with previous protocol studies of design processes.

**I.2.2 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). Gero’s *FBS* ontology has been used in multiple cognitive studies (e.g., Gero & Milovanovic, 2019; Sadeghi et al., 2017; Song, 2014), given that it describes the most important design processes. In the *FBS* ontology, Function (*F*) describes the aims or purposes of the object (i.e., what the object is for). Behavior (*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 the components of the object and their relationships. The ontology is completed by two additional variables: Requirements (*R*), which arise from outside the design, and Descriptions (*D*), referring to 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 the eight design processes of formulation, analysis, evaluation, synthesis, and reformulation I, II, and III, represented as transitions between the ontological constructs. These processes are concerned with: formulation that transforms functions into expected behaviors; synthesis, in which a proposed structure is intended to show the expected behavior; analysis of the structure that gives rise to its resultant behavior; evaluation that compares the expected behavior and the behavior resulting from the structure; and documentation, which presents 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 behavior, 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 coactivation of first occurrences of concepts within the context of the design being processed. Framing is based on the knowledge, experience, and values of a designer, which reflects how they view, represent, and construct problems and solutions. Reframing (*RF*) behavior, which refers to changing the original frame, can occur through three different processes: adding concepts related to previously existing frames; subtracting concepts, and adding new concepts that do not overlap with existing ones.

Whereas framing and reframing (*F-RF*) are terms commonly used in design literature (e.g., Beckman, 2020; Dorst, 2015), most studies on the subject are primarily theoretical or use qualitative methods of analysis. There appears to be no published adequate objective measurement of *F-RF*, for example, by considering the coactivation of first occurrences of concepts. Moreover, the relationship between *F-RF* and the quality of the design solutions has not yet been measured. As an alternative to qualitative methods used to study *F-RF*, this project proposes measuring this fundamental cognitive activity quantitatively using empirical data. While the design cognitive structures, cognitive activity, and performance of experts and novices have been 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 and span of frames in experts is larger than those of novices remains unknown.

This project aims to investigate framing and reframing in design problem-solving.

The objectives of the research are to:

(a) measure framing and reframing quantitatively as the coactivation of first occurrence of concepts generated in design sessions;

(b) measure the size, i.e., number of concepts, and span the semantic distance between concepts of frames;

(c) measure the relationship between framing and reframing and the quality of the design solutions;

(d) compare framing and reframing of design experts and novices;

(e) compare the relationship of framing and reframing 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*. Its intellectual contribution lies in addressing an important gap in our knowledge about how to measure *F-RF* and its effects. An additional contribution is determining the relationship between framing and reframing behavior and design solutions. It will lay the foundation for future interventions that can improve innovation and related problem-solving, both in professional practice and education.

The research proposes a method of empirical and quantitative measurement of *F-RF* to the design decision-making domain, which will offer insight onto the cognitive behavior of the designer during the design process. Any design field can benefit with this study, from those dealing with physical objects such as architecture and engineering to those focusing on virtual objects such as software, gaming, and simulation design. 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**

**III.1 Working Hypotheses**

We formulated the following research hypotheses:

H1*: Framing and reframing* can be measured through the coactivation of first occurrences of concepts.

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

H3: An increase in the occurrence of framing and reframing positively correlates with higher quality of the design solutions.

H4: Experts will have more framing and reframing 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 | --- |

**III.2 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 graphic 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 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 be in the upper half of their class in terms of academic performance. All participants, including architects and students, will be male native Hebrew speakers.

*Procedure and setting*: Experiments will be carried out individually, in a lab setting, for a duration of 45 minutes. All participants will be given a design problem and a task sheet containing general instructions and will be required to sketch while generating as many ideas as possible to solvethe design problem. Participants will be given three minutes to read the problem and the general instructions, prior to producing a final design. They will then be asked to verbalize their thought process, while the session is recorded and a camera captures their sketches. The experimental investigator will respond to any questions, but will not intervene during the session, except to remind subjects toverbalize their thoughts if they are silent for more 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 design solution. At the end of the 45 minutes, the researcher and individual participant will engage in a 15-minute structured debriefing session, where the participant 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 had 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 and modern buildings (Casakin & Kreitler, 2011).

|  |  |  |  |
| --- | --- | --- | --- |
| **Protocol and solutions collection**   * Design task * Videos * Design solutions   **Experts working individually in design sessions**  **Characterize novice and expert F-RF**   * *F-RF* as coactivation 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** | **Protocol coding**   * Segment and code | **Protocol data analysis, and solution assessment** |  |

*Figure 2. Research plan*

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

* Frequencies of *FBS* issues and processes
* 1st occurrence concepts and framing
* Coactivation 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*
* Cumulative occurrence of *FBS* issues and processes and *F-RF*
* Relation between *F-RF* and quality of design solutions

Note: \* See definition below

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

**III.2.1 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 then collect data using think-aloud protocol analysis.

In Phases 2 and 3, the transcripts containing the recorded verbalizations of participants articulated while designing will be segmented, cognitively coded, and analyzed using the *FBS*, *FR-F*, and *P*-*S* coding schemes. Multiple statistical analysis techniques will be employed to obtain models

# Table 2: Project phases, tasks, and timelines



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 following the outline of the measurement methods). 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 previously, enables access to design cognition. The *FBS* codes represent the cognitive activations of the design issues about which the designers are thinking while they design (Gero, 1990; Gero & Kannengiesser, 2004; 2014). 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:

i) *Frequencies of FBS design issues and processes*. They will be analyzed for significant differences arising from 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*. The coding scheme will be augmented by a first occurrence code used to tag potential *F-RF* segments. To this end, transcripts already segmented and coded using the *FBS* design issues codes will undergo a second round of coding for segments containing first occurrences of concepts associated with design *F-RF*. Accordingly, *F-RF*s 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, to test H4, *F-RFs* will be analyzed for significant differences attributable 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*. An aspect of the problem or solution that is introduced for the first time in this project is defined as first occurrence of a concept in that design, which offers an objective and repeatable measure of design change. First occurrence of a concept is important as a unique component in a frame and reflects a shift in the cognitive focus of the designer. To test H1, an algorithm will be used to identify first occurrences of concepts in a frame and then count them as the design process progresses (Lu, 2021).

iv) *Concept coactivation and F-RF*. Frames can be characterized by the coactivation of concepts, either existing or new. 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 coactivation of a first occurrence concept with other existing concepts. To test H1, we will identify and explore the relations of the coactivated concepts in the different frames generated during the design process. To this end, k-means clustering (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 to characterize a frame by analyzing the coactivated concepts and their relationships.

v) *Semantic distance of concepts in F-RF*. The semantic distance of the concepts in a frame can be measured by calculating the semantic distance between its coactivated concepts. Semantic distance is a natural language-processing measurement 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 (Watson et al., 2016e.), and the results of novices and experts will be compared.

*vi) The problem-solution (P-S) index*. The *P-S* index, which measures the cognitive focus on the design problem relative to 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) based 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 greater than 1 means that the designer is more focused on reasoning about the 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 coactivation of first occurrences of concepts, will be analyzed to explore whether it focuses primarily on the problem or on the solution. To this end, segments coded with the *FBS* code will be analyzed for problem-related issues (*P*) and solution-related issues (*S*). *F-RFs* will be analyzed for significant differences attributable to problem and solution spaces )i.e., *F-RF* codes x *P*-*S*). A correspondence analysis will then be performed 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) *Cumulative occurrence of F-RF*. To test H1, the cumulative occurrence of *F-RF* will be calculated as a sum 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 the design distributions, which have no time dimension. It measures the rate at which participants have expended cognitive effort on the design session. The cumulative occurrence (*C*) of *F-RF* () at segment (*n*) is *Cx* = *xi*, where(*xi*) equals 1 if segment () is coded as (*x*), and 0 if segment () is not coded as (). Plotting the results 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 attributable to expertise.

viii) *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.

# Table 3: Research hypotheses and measurements

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Research hypotheses | | | | |
| Measurements |  | H1 | H2 | H3 | H4 |
| i | --- | --- | --- | --- |
| ii | --- | --- | --- | X |
| iii | X | --- | --- | --- |
| iv | X | X | --- | --- |
| v | --- | X | --- | --- |
| vi | X | --- | --- | X |
| vii | X | --- | --- | X |
| viii | --- | --- | X | --- |

*Coders and coding reliability*: Two independent coders will simultaneously segment and code the transcripts, repeatedly breaking down 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. Intercoding 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 intercoder 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 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 *FBS* 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 be used to identify frames, explore different aspects of frames, and investigate their relationship with the quality of design solutions. A frame is independent from the categories it creates. Consequently, the proposed measures will facilitate the determination of whether a frame is located in one design category/space (e.g., the solution space or the function space), or in multiple design categories/spaces (e.g., across problem and solution spaces or 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 offer insights into the relationship between frames and the different design spaces where designers, both novices and experts, are applying their cognitive efforts to view, represent, and construct problems and solutions during the design process.

## III.3 Preliminary Results

## There not yet any preliminary results for the proposed project. However, I have experience in protocol analysis, and I have acquired further experience in the use of the research methodology by participating in an ongoing research led by Dr. Hadas Sopher and Prof. John Gero dealing with the use of immersive (*iVR*) and non-immersive environments in design crit sessions, and in which one instructor and third-year architecture students have participated. (For further details about the use of the methodology see Kan & Gero, 2017;and Sopher & Gero, 2021).

## My ability to use the methodology can be adduced from my contribution to this ongoing project of analyzing and coding part of the data collected by Dr. Sopher using the *FBS* ontology. Based on this, I have calculated the distribution of the first occurrence (*FO*) of concepts generated during the design sessions. The method has been proof, and I present here an exemplary result of the *FBS* and first occurrence of concepts that I am going to use in the proposed project. Figure 1 shows the average number of *F*Os per minute for *FBS* issues generated by the instructor and the students in *iVR* and non-immersive design crits. As can be observed, the highest number of *FO*s generated by the instructor in the *iVR* and the non-immersive environments corresponds to Bs followed by S. Similar results were found for the students, but in the opposite order. The instructor produced a higher number of *FO*s than the students in each of the environments. While the *F*Os of the instructor were higher in the non-immersive crits than in the *iVR*, the opposite was observed for the students.

## III.4 Existing Research Conditions

The principal investigator (*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 two assigned Research Assistants (*RA*s), who are available for the current research project. The research is guided and supported by Professor John Gero, an eminent international research authority in the design field (see Appendix with enclosed support letter). He has published numerous publications in leading journals related to the main topics of the research proposal, and his design research publications have garnered 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 Ariel University’s School of Architecture. It is a well-ventilated and noise-isolated room, with adequate furniture for conducting design sessions. The room is accessible and available for the intended activity.

**III.5 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 offer further working hypotheses for future research. The outcomes of this project may affect design education with a change on the pedagogy in education as well. Considering that an increase in the occurrence of *F-RF* would produce higher quality of the design solutions, educational programs might benefit from developing pedagogical approaches supporting and encouraging more *F-RF* during the design process. This could form the bases of a tool that could change design practice. Gaining deep insight into *F-RF* behavior in novices and experts will contribute to understanding how students can be helped to develop their design expertise.

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

Another issue concerns difficulties in finding good coactivation of design concepts related to the framing activity. Coactivation is related to the clustering of concepts. If the coactivation clustering does not produce the expected results, we will control the clustering parameters affecting the connectivity among concepts by changing the threshold for clusters for coactivation until a suitable cluster is found.

The study plans to recruit senior architects from leading architectural offices in Israel as participants. However, finding and receiving 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 obtain consent. If this recruitment proves to be difficult, the *PI* will seek assistance of colleagues at the university. If that, too, is unsuccessful, the *PI* will use a professional manpower company to contact potential participants from leading 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 |
| Casakin, Hernan | 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 (*RA*s), both graduate students, will be employed for the project. Following comprehensive training, including general instructions on research procedures and specific guidance on coding and analysis of design protocols, the *RA*s 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 the *Ra*s’ work, and *RA*s will report routinely to the PI. Weekly update meetings will be conducted during data collection and data analysis. Upon completion of the experiment, the *RA*s will collaborate in creating transcripts of the verbalizations of the students’ and architects’ design sessions, in segmenting the transcripts, in protocol analysis using the coding, as well as in cognitive characterization of the transcripts as statistical models. *RA*1 will work full time during the three years, at the rate of NIS 6000 per month (NIS 216,000), and *RA*2 will work part time (50%) over two years, at the rate of NIS 3000 per month (NIS 72,000). A total cost of NIS 288,000 is projected personnel for the duration of the proposed research project (three years).

**Supplies & Materials**

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

**Justification for requested Supplies & Materials:**

**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 | 2000 |  |  |
| **Total Services** | 9**,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. Three referees are needed. 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 time for this task is 40 hours, at the rate of NIS 300 per hour. The total cost is NIS 12,000.
4. Eventually, the services of a manpower company may be requested to recruit architects to participate in the experiments. The total cost is NIS 2000.

Appendices

Collaborations – In order to prevent conflicts of interest in the evaluation process, the names of the researchers collaborating with the PIs submitting this proposal – in this proposal and in other collaborative projects (referring to joint publications, joint grants, etc.) in the past five years – should be included.

Letters of collaboration should be uploaded only for the researchers collaborating in this specific research. The collaboration letter should be in English, no more than two pages in a legible font and size and include a signature and logo of the collaborator.

**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 |
| Ancillary Equipment (camcorder) | 1,700 | 0 | 0 |
| Ancillary Equipment (tripod) | 500 | 0 | 0 |
| Ancillary Equipment (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 at a cost of 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 will cost NIS 500.
5. Micro SD will be used to record the design sessions for about 30 hours, costing NIS 150 in total.

**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 constructive research environment include office supplies, photocopies and printouts, computer supplies, publication charges for 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 | 9,650 | 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 | 22,916 | 19,805 | 15,725 |
| Equipment (no overhead on this item) | 0 | 0 | 0 |
| **Total budget** | **157,716.00** | **136,305.00** | **108,225** |
| **Annual average** | **134,082.00** | **134,082.00** | **134,082.00** |
| 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**

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| --- | --- | --- | --- |
| 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 |
|  |  |  |  |

PI1 Name: Assoc. Prof. Hernan Casakin

# LIST OF PUBLICATIONS

**Hernan Casakin**

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