UNDERSTANDING THE IMPACT OF RECOGNITION AND RECALL ACTIONS ON ARCHITECTURAL DESIGN PROCESS

Noor Kadhim Saeed AL-KHAFAJI[1], Can UZUN [2*]

[1, 2] Altınbaş University, Faculty of Engineering and Architecture, Department of Architecture, İstanbul, Türkiye,
[1] ORCID No: https://orcid.org/0009-0008-5886-158X
[2] ORCID No: https://orcid.org/0000-0002-4373-9732

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Abstract

Every architect has a personal archive of pictures and details that they use to help them develop their architectural design that, for the most part, embodies their vocabulary within their memory from earlier experiences. The retrieval mechanism for these experiences is vital in the design process. This study examines the relationship between retrieval and design action, particularly through the specified codes: recall, recognize, guess, propose, analyze, and evaluate to understand the underlying design strategies based on these retrieval actions. This study applies the investigate-and-redesign method to reveal the retrieval and design action patterns and conducts protocol analysis through the think-aloud procedure. We use a two-stage quasi-experiment method for "investigate and redesign" parts. In the investigate part, subjects study the twenty given building facade images, and in the redesign part, subjects are asked to design a new facade, and they are allowed to apply free recall from the studied examples. Results show that designers are shifting or modifying their strategies on retrieval and design actions to minimize the error rates in design and accomplish the task in a given time. Design actions are more focus-demanding than retrieval actions. Retrieval actions appear with free associations, and focus shifts occur frequently in retrieval actions. All the codes of retrieval action and proposed code of design action are associated. Overall, this study reveals the nature of the occurrence pattern between retrieval and design actions by providing different design strategies for different retrieval actions.

TANIMA VE HATIRLAMA EYLEMLERİNİN MİMARİ TASARIM SÜRECİNE ETKİSİNİN ANLAŞILMASI

Anahtar Kelimeler
Araştır-ve- tasarla
Protokol Analizi
Hatırlama Eylemi
Tasarım Eylemi
Bellek

Öz

Her mimar tasarım sürecinde önceki deneyimlerinden topladığı kişisel bir bellek arşivine başvurur. Bu deneyimler için hatırlama mekanizması, tasarım sürecinde önemli bir yer tutar. Bu çalışma, hatırlama ve tasarım eylemi arasındaki ilişkiyi tanımlanan kodlar aracılığı ile incelemektedir. Bu kodlar; hatırlama, tanıma, tahmin etme, önerme, analiz etme ve değerlendirme olarak belirlenmiştir. Bu çalışma, hatırlama ve tasarım eylemi ilişkisini ortaya çıkarmak için araştır-ve-tasarla yöntemini uygular ve yüksek sesle düşünme prosedürü aracılığıyla protokol analizi yöntemini analiz yöntemi olarak kullanır. Araştır-ve-tasarla yöntemi için iki aşamalı bir yarı-deney yöntemi kullanılmıştır. Deney süresince, denekler verilen yirmi bina cephesi görüntüsünü inceler ve tasarım bölümünde, deneklerden yeni bir cephe tasarlamaları istenir. Tasarlama sürecinde deneklere inceledikeri örnekleri serbestçe hatırlamaları için izin verilir. Sonuçlar, tasarımcıların tasarımdaki hata oranlarını en aza indirmek ve tasarım görevini belirli bir sürede tamamlamak amacıyla hatırlama ve tasarım eylemlerindeki stratejilerini düzenleidklerini göstermektedir. Hatırlama eylemi serbest çağrışımlarla ortaya çıkar ve odak kaymaları hatırlama eylemleri ile birlikte sıklıkla meydana gelir. Sonuçlara göre hatırlama eylemi kodları ile tasarım eylemi kodları birbirleri ile ilişkili belli örüntüler üzerinden meydana gelir. Bu çalışma, farklı geri çağırma eylemleri için farklı tasarım stratejileri sağlayarak, geri çağırma ve tasarım eylemleri arasındaki oluşum örüntüsünün doğasını ortaya koymaktadır.

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* Sorumlu yazar: can.uzun@altinbas.edu.tr
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1. Introduction

The designer's memory is the most critical information processing mechanism for evaluating the information, consciously selecting the categories, and shaping the method to analyze design problems (Shen, Yao, Bao, and Yu, 2023). Moreover, memory is the retrieval source of the experiences of any information. Experiences contribute to finding a starting point for any design proposal and developing it. Eastmen, Newstetter, and McCracken (2001) indicate that architectural memory is structured earlier than an architecture education, with the built environment in which we pursue our whole life. Architecture education contributes to this process by increasing its curriculum and course contents with various experiences through projects, readings, and field trips (Eastmen, Newstetter, & McCracken, 2001). This experience creates a broad vocabulary for the association of architectural projects, and the association facilitates architectural knowledge processing.

Eastman et al. (2001) suggests that design retrievals are complex processes based on structuring architectural knowledge and constructing its association with architectural experience. In other words, retrieval actions can be a way for knowledge or experience transfer act during design. Hence, retrieval can be important for guiding designers in developing creative solutions using their existing design knowledge pool.

This study aims to understand if, during the design process, strategies for different retrieval actions, such as recall, recognition, and guessing, can organize the design problem's management (meta-planning) for different design objectives and if different retrieval processes can lead to intuitional or analytical design approaches. Each retrieval approach may contribute to the design from various perspectives. This research will provide further information to understand better the relationship between memory retrieval and design action in the design problem-solving process to address the designer's problem-solving strategies between memory and design actions.

The following chapters illustrate the retrieval states and their importance in design processes, explain the investigate-and-redesign quasi-experiment method, and finally explain the results.

2. Literature Review

Schacter (1995) defines memory as the capacity to recollect information acquired throughout time. At the same time, William (1891) defines memory as the process by which the outside world and ideas are stored for us to recall later. On the other hand, memory is critical for problem-solving and problem recognition, which entails processing information by the brain and its application to decision-making.

Coding, storing, and retrieval are important activities for the memory system (Smith, 2014). Coding transforms the information the brain gets from interactions with the outside world into a form that the brain can comprehend and easily store. The location of the information's storage—long-term or short-term memory—relates to storing and the ability to recollect facts or information that have already been encoded and stored in the brain is linked to retrieving it. These three processes are essential for forming human memories, which are then held and eventually retrieved.

Memory retrieval includes recall, recognition, and guess actions (Freund, Brelsford, & Atkinson, 1969; Watkins & Tulving, 1975; Uner, 2018; Watkins & Gardiner, 1979). Freund et al. (1969) define recall and recognition as the functional depiction of memory and state that recall and recognition differ not because of the storage processes but because of the retrieval processes (Freund et al., 1969). According to Watkins & Tulving (1975), recall appears with the search activity and recognition afterward. The relationship between recall and recognition has been discussed in various circumstances. It has been questioned whether these tasks represent distinct cognitive processes depending on the kind of retrieval cues (Uner, 2018). Uner defined that the only difference between recall and recognition is the available cue information. The recognize action is activated if the available cue duplicates the target (retrieval trace). If not, recall action is activated (Watkins & Gardiner, 1979). This order of retrieval actions parallels the design problem-solving process. The designer first proposes an idea by recollecting their earlier experiences, whether knowingly or not, and recognizing its context of use. Investigating the occurrence pattern of the retrieval cycle can be a worthy point for understanding the retrieval strategies and how this cycle can be effectively organized during the design process.

Cleary (2018) defines recognition memory as identifying the ability of learned items from non-learned items. Recognition memory has two concepts: familiarity and recollection; the familiarity concept is a fast and weak recollection type of process and is easily affected by external factors, while recollection duration takes longer and makes strong associations with past experiences; however, for both concepts of recognition, an external stimulus is necessary to retrieve an experience (Rugg & Yonelinas, 2003; Gardiner, Ramponi, & Klavehn, 2002). The external stimulus in design that triggers the recognition is the verbal or visual externalization of the ideas. So, proposing new ideas by searching the memory by the recall can give the potential stimulus for recognition to detect the familiar part of the idea and integrate it into the design process familiarly or innovatively. The underlying occurrence pattern of recognition can help to understand how to create connections between ideas in a design process.

Tulving (1985) proposes knowing and remembering concepts for recognition memory, creating a relation between knowing and remembering while considering both actions as a different activity. Donaldson (1996) added a third concept for the recognition memory: guessing. Although guessing is an intuitive decision-making activity, the design process can benefit from its vague, uncertain nature for a creative design idea. The occurrence and the relation of this retrieval action with the design action can reveal some design decision-making strategies.

Recall, recognition, and guessing are integral in the design decision-making process. The interplay between different retrieval actions can develop different design strategies, too. According to the design problem, one may change his/her retrieval strategy to find the design solution easily. This study aims to understand the nature of the above-mentioned information. For this purpose, firstly the next section will present the literature related to memory retrieval in design, and both the importance of memory retrieval in the literature and the gap in memory retrieval will be explained.

2.1. Memory Retrieval in Design

In design problem-solving, memory retrieval plays a crucial role. Eastman directly indicates the memory issue in design by mentioning that retrieving the related design ideas provides a contextual frame of the design problem space (Eastmen et al., 2001). Eastman defines the analogy with memory retrieval in design. Akin (1990) indicates that knowledge from memory shapes generative thinking, which is called design. Hence, retrieval from memory is necessary for the design process to be achieved. Goldschmidt (1991) sees action as memory retrieval through visual analogy, and states that visual analogies can improve the design problem-solving process. Verstijnen, Van-Leeuwen, Goldschmidt, Hamel, and Hennessey (1998) define memory as the structured information location retrieved in the mental imagery process.

In the context of memory retrieval in deisgn, the literature has been associated with many different design strategies, such as, analogical thinking, contextual framing, and developing new approaches to problem-solving. Studies in the literature have made significant contributions to understanding the effects of these actions on the design process strategies.

Gero and Milovanovic (2020) argue that memory retrieval as analogy is useful for proliferating the design problem solutions. Yuan, Liu, Lu, Yang, and Hao (2023) developed their research on the optimization of the memory retrieval process and analogies by balancing the abstraction level of the samples retrieved from the memory. Chan, Dow, and Shunn (2015) experimented to understand the analogical reasoning process in design while stating that experienced designers are more prone to make analogical reasoning and memory retrieval than novice designers and they propose structured analogical training to improve the design education. Atilola and Linsey (2015) compare different means of visual analogies while criticizing the problem of design fixation as a result of analogies. Koronis, Casakin, Silva, and Siew (2021) compare the effect of verbal, visual, and detailly instructed stimulus on the analogical reasoning of design students, and they suggest textual-based stimuli for analogies enhances the creativity of novice designers. Casakin (2004) claims that visual analogies through retrieval enhance the design solution quality.

Jia, Jiang, Hu, and Qui (2022) study the stimuli to trigger the retrieval process in design and state that the over-stimuli for retrieval may limit the creativity of the novice designer with superficial design fixations. However, Jia et al. reveals that design fixation increases the quality of design and has a strong relation with different design features (focus-type and broad design features). According to Jia et al. using targeted design fixations for specific design features may contribute to the designers' innovation. All these statement shows retrieval process has direct relation with the design process moreover as highlighted in cited work of Jia et al. fixation and thinking are intertwined actions throughout the design process hence memory retrieval is an inseparable part of design process.

In their study, Koronis, Casakin, and Silva (2023) indicate that memory retrieval in the analogy process is important to construct innovative ideas in the design process and propose visual stimuli for enhancing the analogies. According to Koronis et al., visual stimulus firstly increases the designers' ability to create analogies and enables the emergence of new ideas. On the other hand, Koronis et al. states that visual stimuli provide a concrete framework for a possible solution to abstract design problems and visual stimuli helps novice designers solve problems with a broader perspective rather than their mis-preconceptions.

Shen et al. (2023) analyze the categories of retrieved memory examples and states that the categorization of retrieved memory examples facilitates the optimization of the designer's knowledge. This study shows that designers can use categorized memory examples more efficiently, make more accurate analyses and evaluations with categorized examples, and improve their designs with transitions between different categories by understanding the relationships between different categories. Crismond (2001) proposes investigate-and-redesign action to examine the retrieval processes in design action. According to Crismond, expert designers apply analogies while retrieving the structured knowledge in their memories; however, interestingly, Crismond reveals that designers do not use every piece of information they retrieve from their memory. Novick (1998) asserts that experts structure successful analogies through retrieval from their memories.

This study differs from the existing literature by focusing specifically on recognition, recall and guessing, and their relation to design actions and by exploring the underlying design strategies based on these retrieval actions.

Firstly, this study contributes to the literature with its findings regarding the relation between design and retrieval actions. Secondly, understanding the nature of occurrence patterns for the retrieval actions reveals different decision-making strategies that contribute to the literature by guiding novice and expert designers in developing their planning through the design problem-solving process. Moreover, although retrieval actions are emergent and involuntary reflexes, being aware of them can guide the designers, and they can track their path to understand if they are in the right decision-making process. For expert and novice designers, awareness of retrieval decision-making strategies can provide self-confidence for a more controlled design process. Novice designers can develop effective design strategies with this awareness. Strategies for retrieval cycles in the design process can also contribute to design education. It can contribute to creating a plan in design education in terms of memory instruments that can help the design process correctly.

3. Methodology

Research examining the cognitive processes has always become a challenging task. Most importantly, the validity control of the examined cognitive processes is critical. Watson (1920) proposes verbalization for studying mental processes and asserts that verbalization is a valid externalization method of thinking. Ericsson and Simon (1980) indicate that the investigation of internal states is possible through verbalization, and they accept verbal descriptions as the source of valid cognitive data. Moreover, Ericsson (2017) states that verbalization does not interfere with or change the subjects' activity.

Ericsson and Simon (1980) classify the verbalization protocols into three categories: think-aloud, concurrent, and retrospective. Verbalization is a simultaneous action with the subjects' activity when thinking aloud technique is applied; when the concurrent protocol is used, the performance is ended, but the information is still active in the short-term memory of the subject, while the retrospective method is applied after the subjects' activity completed (Ericsson & Simon, 1980). This analysis procedure of verbalization reports is called protocol analysis (Sauder & Jin, 2016).

The protocol analysis method is utilized in educational, psychological, architectural, and other disciplines that are interested in learning more about cognitive processes (Sauder & Jin, 2016). The transcripts of (think-aloud protocols) are used to study the cognitive processes that underpin task performance after they have been recorded or filmed as data (Someren, Barnard, & Sandberg, 1994). This technique is meant to be uninterruptible and question-free for the participants; it is a straightforward and easy-to-use instrument for investigating and comprehending how people think and the kinds of abilities and tactics they employ while addressing difficulties (Sauder & Jin, 2016). Verbalization skills are among the most important requirements for obtaining the right protocols.

In this study, investigate-and-design process is utilized as proposed in Crismond (2001) with the protocol analysis through think-aloud protocols to collect transcriptions and analyze the relation between memory and design processes. Firstly, the experiment setup was organized to collect the think-aloud protocols and analyzed them through the codes we defined.

3.1. Design of the Quasi Experimental Model

This study applies a quasi-experiment model to trigger the memory effect on the design process. This quasi-experimental model is based on the two-step experiment, stage 1/investigate, and stage 2/redesign, involving ten architect participants.

The quasi-experimental model with a two-stage (review and redesign) design combines practical application with analysis, unlike abstract theoretical models and limited observational studies. This approach enables exploring design cognition from a dynamic perspective, not only with theoretical or observational limitations, but also by providing applicable insights based on real-world design scenarios.

In our study, the independent variable of the quasi-experimental method is the previously shown images (investigate phase), while the dependent variables are the design process (redesign phase). The quasi-experimental model is employed due to the absence of any manipulation of the independent variables, the lack of a control group, and the goal of understanding the direct effects on the dependent variables. The independent variable aims to trigger memory retrieval in the design process and to understand the relation between memory retrieval states and design action.

The first stage prepares the participants for the think-aloud-experiment. It presents twenty architectural images, each representing a different architectural housing project's facades with various scales worldwide. The selection criteria of the architectural images to be shown to the participants are visually and design-wise diverse examples not to create a design fixation bias. So, the visuals contain random styles from architectural facades. The participants are asked to study the projects shown one day before the think-aloud experiment. In the second stage of the experiment, the think-aloud procedure is applied. At the beginning of the experiment for stage 2, architects are tasked with designing a new two-story house facade using pen, pencil, and paper, and they are told that they can do free recalls from their early studied building facades. In this stage, the subjects are asked to think aloud to express their internal design states. During stage 2, subjects rely only on their memory; no signals are provided during the experiment. Figure 1 represents the visuals from investigate and the sketches of participants from design phase.

Figure 1: Examples of façades presented during the 'investigate' phase and corresponding design sketches created by participants in the 'design' phase.

Data acquired from the recordings is analyzed using a coding scheme that has been created. The first stage of the experiment to examine the examples is 30 minutes, and the second stage is agreed to be 15 minutes for each participant. Both stages of the experiment are illustrated in Figure 2.

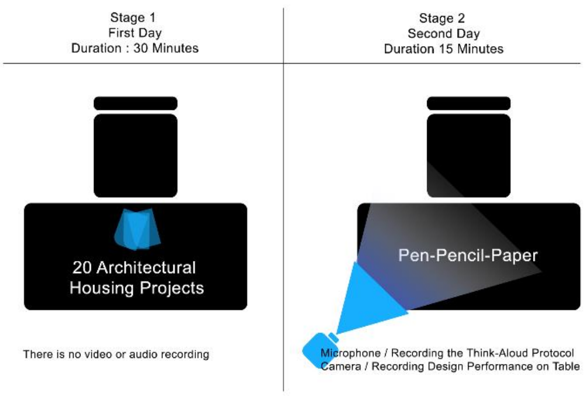

Figure 2. Diagram of the Experimental Setup Used in Both Investigation and Redesign Stages, Illustrating Key Components and Processes (by the Authors)

3.2. Participants

3.2.1. Participants overview

This experiment consists of ten architect participants. The participants' ages ranged between 25 and 30 and were early-career professionals. The selection of this early-career professional group may also minimize the potential effects of design fixation in the experiment and help to obtain a more homogeneous group of participants.

3.2.2. Ethical consideration

Before the experiment, participants were informed that the recordings would not show any personal details about their identity and voices and that only the researcher could use and analyze them in private after signing consent letters from the participants.

After participants sign consent papers allowing the use of their data, this experiment is recorded (audio and video). This study was conducted in accordance with the ethical standards set forth by the Altınbaş University Scientific Research and Publication Ethics Committee and received approval from the Scientific Committee and received approval from the Scientific Research and Publication Ethics Committee at Altınbaş University. The ethical committee approval number for this study is 2024/14 and the approval date is 02.05.2024.

3.2.3. Segmentation and Coding

Data transcription, the meticulous first step of protocol analysis, was undertaken carefully. 150 minutes of verbalization data was meticulously transcripted for ten experiments, each having 15-minute recordings. After the transcription of the verbal data, the segmentation phase is completed.

The subject's smallest meaningful moves are called segments. Firstly, to encode the verbal data, the smallest meaningful parts are extracted from the verbal data; in other words, attention/move shifts are decided on the protocols. After segmentation of the protocols, we obtained 29, 19, 21, 20, 24, 18, 33, 24, 21, and 25 segments for each ten experiments, respectively.

The second phase, equally significant, involves assigning a code to each segmentation so that the changes in the subjects' activity can be examined. To complete the coding phase, a coding scheme must be meticulously organized according to the research question, which aims to understand the relation of the moves from the design and memory phases. The coding scheme used in this paper is taken from Sauder and Jin (2016) but is reconfigured according to experiment purposes. We designed two categories: design action and retrieval action (Table 1).

Table 1. Segmentation and coding table

Experiment	Codes	Description
Design action	Propose	Starting a new idea about the facade
	Evaluate	Determinate whether to continue or make changes to the design
	Analyze	Checking the current step of the design
Retrieval action	Recognition	Familiarity - Knowing the details with cues
	Recall	Retrieving details from memory without any cues / Free Recall
	Guess	Feeling as knowing experience

Design action includes propose, evaluate, analyze actions which are the essential activities of a design process. Retrieval actions contain recognition, recall, and guessing actions to test the memory states of the cognitive actions.

Propose action stands for the ideation processes, evaluate is the determination of whether to continue or make changes, and analyze is the current state of the experiment's examination.

Recognition occurs when a cue is available and is defined as knowing the available cue. Recall is the retrieval process of memory without any cues, and in this experiment, free recall is applied. Free recall permits subjects to recall the studied items in any order (Cleary, 2018). Guessing is the feeling of knowing the retrieval process.

During the coding process, we followed different criteria for all the codes. After segmenting each design move, we analyzed each segment using the code definitions in Table 1. Firstly, the related move in the segment must semantically fit the code definitions in Table 1. Secondly, there were some obvious clues regarding the codes. Participants mainly repeat the verb "remember" or a similar verb for remember code. This helped us to find the remember code easily. Such a case is also valid for the guess action, as the participant directly spells the word "guess" when guessing something. For the recognition task, we look at some recognition clues in the segments, using words such as "obvious," "I see," and "I know this." This kind of phrase conveys familiarity or knowing the details with some cues. For design actions, if a designer verbally or visually creates or adds a new idea about the facade, we directly define these segments as proposed. If there is a decision about the proposal as "this fits" or "*the proposal* can be.." we coded it as evaluate action. In the analysis code, if the participant inquiries about the relations and inherited structure of the proposed ideas, then we code it as analyze code. In Table 2 we represent some partial examples from the experiments showing the transcript samples and their related codes.

Table 2. Example coding scheme from experiment 1, 2, 6 with transcripts

	Time Stamp	Propose	Evaluate	Analyze	Recognize	Recall	Guess
1	2:16-2:35	-	-	-	-	I remember such column in the examples.	-
	2:35-2:51	It is obvious it will be black porcline column.	-	-	It is obvious it will be black porcline column.	-	-
	2:51-2:57	I guess there were stairs somewhere.	-	-	-	-	I guess there can be stairs somewhere.
	2:57-3:26	From its form I see that I can draw one floor mass.	-	-	From its form I see that I can draw one floor mass.	-	-
	3:26-3:49	-	This mass fits.	-	-	-	-
2	2:02-2:22	-	-	-	-	I remember two masess one is higher than the other	-
	2:22-3:10	-	-	I guess this relation is a question.	-	-	I guess this relation is a question.
	3:10-4:09	I will draw the stairs in this shape, I remember it was like this	-	-	-	I will draw the stairs in this shape, I remember it was like this	-
	4:09-5:01	I will add this mass as I remember seeing it in the images	-	-	-	I will add this mass as I remember seeing it in the images	-
	5:01-5:36	I see a sliding glass door here	-	-	I see a sliding glass door here	-	-
6	0:38-1:03	I know there are windows in the new classic style	-	-	I know this, there are windows in the newclassic style	-	-
	1:03-1:26	-	-	-	-	I remember some louvers on the facade	-
	1:26-2:36	I guess stone can fit on this surface	I guess stone can fit on this surface	-	-	-	I guess stone can fit on this surface
	2:36-3:04	columns can be…. I guess	columns can be…. I guess	-	-	-	columns can be…. I guess
	3:04-3:14	I guess this will be stone	-	-	-	-	I guess this will be stone

4. Findings and Discussion

We analyzed the protocols under four headings in their respective order: occurrence pattern of codes to understand the nature of simultaneous and successive patterns of codes; duration, occurrence, and average-duration-per-segment (ADpS) comparison to reveal the focus demanding codes and their similarities or differences; segment duration to measure the attention shifts for each experiment, and finally code correlation to inquire the pairwise significant relations between the design actions and retrieval actions.

4.1. Occurrence Pattern of Codes

The occurrence of the actions has a certain pattern for each experiment. The occurrence pattern reveals the code shift behavior of the subjects (Figure 3). The code shift occurs along with the active-inactive actions and codes' simultaneous or successive occurrences. Simultaneous actions are associated actions. Successive actions can trigger actions for each other. Detailed control of the simultaneous actions reveals some action codes depend on other codes while the vice-verse may not be necessary. Nine out of ten experiments start with the propose action and the occurrence of the propose action has no specific location in the timeline of the experiments. However, analyze and evaluate actions do occur in the middle or end of the experiments instead of at the beginning of the experiment. This is a natural result of the design problem-solving process because the solution is initially proposed, evaluated or analyzed. On the other hand, this finding is parallel to the findings of Malhotra, Thomas, Carroll, and Miller (1980) in their study examining the cognitive processes in design, emphasizing that the design evaluation phase occurs after the design production phase. Additionally, figure 3 does not represent of any specific occurrence pattern of design action codes except the evaluate code. When the evaluate code is active, the other codes for both actions are inactive. The evaluation process is a stop point for understanding the existing situation of the project process; hence, evaluate code is an independent code.

Retrieval action codes follow a certain occurrence pattern and interact with the proposed code of design action. All the retrieval actions (recognize, recall, guess) always appear distinctly and successively. Jennings and Half (1980) demonstrate that recall and recognition take similar processing capacities in memory load; hence, these two memory retrieval states have some common processes. This can be why the memory retrieval states occur successively to decrease the memory load. One can recall things after recognition is activated or recognize things after recall is activated. On the other hand, this cognitive order can be a result of triggering events.

Occurrence of recognize, recall, and guess actions has an obvious association with the occurrence of propose action. Recognize, guess, and propose actions appear simultaneously while recall and propose actions occur successively.

Propose, recognize, and guess codes are the concomitant codes. Hence, these codes can be associated with each other. When the either recognize or guess code appears, propose code is always active with a small exception. However, vice-versa happens rarely. This means propose code must be always active for recognize and guess codes. Hence recognize and guess codes depend on the propose code, while propose action is independent to recognize or guess codes.

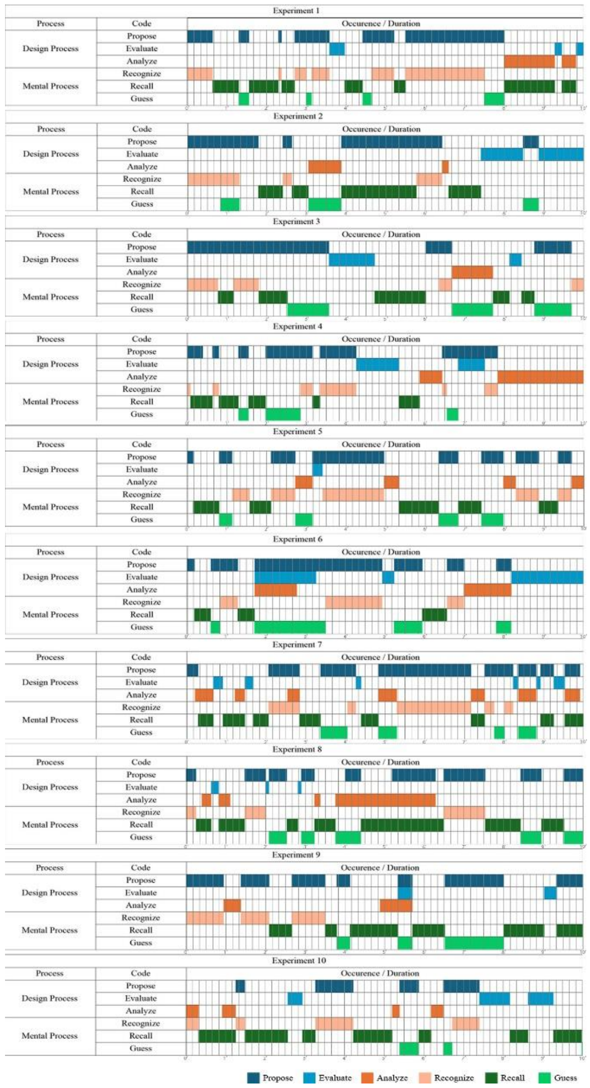

Figure 3. Chronological Representation of Design Actions and Information Retrieval Processes During the Design Task for each ten experiments (by Authors)

Recall and propose codes can be sequential actions, as after most of the recall codes, the proposed code is activated. To start a propose code, the recall code must be ended. They occur independently, but they can be the triggering factors for each other.

The occurrence of codes reveals that all the codes of retrieval action and propose code of design action are associated. This interaction is important for the exchanging design information from memory to proposal.

4.2. Duration, Occurrence and ADpS Comparison

Duration, occurrence, and ADpS are the numeric metrics that compare actions and codes. They convey information related to action/code focus, frequent action/code, and the relation between the action/code.

In this section, we compare the duration, occurrence, and ADpS metrics for actions and then analyze the average value of the metrics for the actions' codes. Figure 4 illustrates the action-based comparison, while Figure 5 represents the code-based comparison.

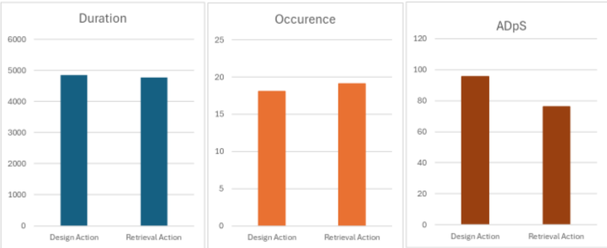

Figure 4. Bar Charts Depicting Duration (in Seconds), Occurrence (Count), and ADpS Values (Rate) for Design and Retrieval Actions (by Authors)

Overall evaluation of the actions proposes that the total duration of the design action (4854 sec.) slightly surpasses the retrieval action (4779 sec.). The number of occurrences is higher in retrieval actions (191) than in design actions (181). Interestingly, the ADpS of the design action is higher than the retrieval actions. According to these findings, average-duration-per-segment (ADpS) is higher in design action than retrieval action; hence, the design actions are more focused than retrieval actions.

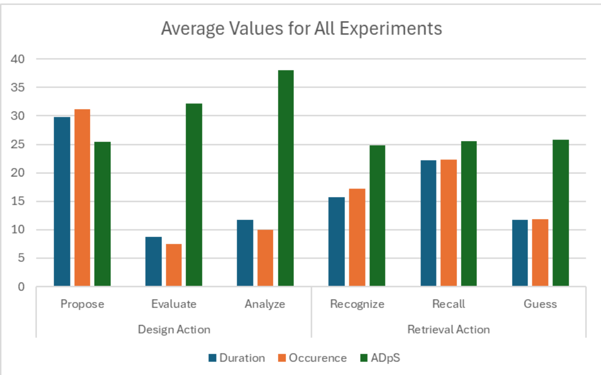

Figure 5. Normalized Bar Chart Comparing Duration (in Seconds), Occurrence (Count), and ADpS Values (Rate) for Propose, Evaluate, Analyze, Recognize, Recall, and Guess Codes (by Authors)

The action-based comparison of duration, occurrence, and ADpS reveal that throughout the experiments main structure of the design process continues along with the design action focus while retrieval actions appear as an auxiliary part of the design. In this way Design actions exhibit greater consistency compared to retrieval actions. Short-term retrieval focus shifts facilitate efficient memory scanning. while focusing in design actions helps the design decisions be consistent.

We also compare the duration, occurrence, and ADpS for each code using the average values from all the experiments.

Codes are ranked in descending order, as propose, recall, recognize, guess, analyze, and evaluate, for the duration and the number of occurrence metrics. The recall has the second highest value for both duration and the number of occurrences. So there is a parellelity for both recall, and propose action. As explained in literature analogies can be triggering actions for ideation process in design. Recall action is the main source from the memory for propose actions as this action retrieves previous design experiences, knowledge and information. Hence during the design activity for all experiments, recall becomes the most applied retrieval action state. Evaluate and analyze actions are the least applied actions, and this must be due to the limited experiment time as the participants mainly focused on the generative tasks to complete the experiment within the given time. This time limitation may create a bias in the findings.

For ADpS, the descending order is as follows: analyze, evaluate, guess, recall, propose, recognize. This order reveals the most focus demanding code to be analyze and least focus demanding action to be recognize. ADpS value of analyze action is the highest, as during the experiment, participants' examination of their proposal takes time to understand, comprehend and interpret.

In this perpective the most focus-demanding actions appears to be the analyze action. Opposed to analysis, recognition action is the least focus-demanding code. Rugg and Yonelinas (2003) indicate that one type of recognition appears as a familiarity memory state, and this action is a fast and momentary action. The findings of these experiments are parallel with Rugg and Yonelinas' assertion.

On the other hand, recall and guess actions are more focus-demanding than the recognize action. In these tasks, memory tries to retrieve previous data, increasing the focus duration. The difference between recall and guess actions is that the first is a knowing experience, while the second is a feeling-as-knowing experience, as defined by Hart (1965).

4.3. Segment Duration

Figure 6 shows segment duration to illustrate the attention shifts for each experiment and provides a holistic perspective for the whole experiment process with the number of attention shifts. When the segment duration increases, the attention duration rises, too, and vice versa. The average attention shift number for all experiments is 23,4. For 10-minute experiments, the average attention shift per minute is 2,34. For each minute, participants of the experiments shift their attention and actions between 2 or 3 times during the experiment, and the average duration for each segment is almost 20-30 seconds. The total number of segments for each experiment ranges between 19 and 33.

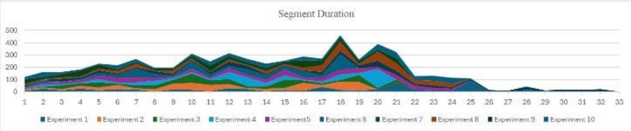

Figure 6. 2D Area graphs shows segment durations (in seconds) for each experiment. The general trend is more short segments at the start, longer segments in the middle, and fewer, shorter segments at the end (by Authors)

Figure 6 not only presents the numeric durations of the segments but also provides an insight into designers' design strategies and cognitive workload in the design problem-solving process. We observe three strategic parts of the design process through all the experiments: the initial, middle, and final phases. Each phase has different patterns in terms of segment durations. Initial segments tend to change faster to explore potential design solutions and plan the design process. In the middle segments, designers' concentration intensifies to comprehend and make design decisions, so the mid-phase of the experiment can be the critical design decision phase, and the segment durations peak. In the final segments, the designer makes the final adjustments with fewer iterations on the design as the design decision takes its final shape, the cognitive workload decreases slightly, and segment durations decrease too. Although it is defined as the initial, middle, and final phases, these phases cannot be reflected on the X-axis in Figure 6. This is because the number of segments for each experiment is different, and therefore, each experiment's initial, middle, and final phases are different. Consequently, showing 10 different initial, middle, and final stages on the same graph would be quite complicated. On the other hand, it does not aim to determine a definite initial, middle, and final phase starting and ending point. However, the general trend observed for all experiments is that there are many short-term segments at the beginning, longer-term segments in the middle, and shorter and fewer segments at the end.

4.4. Code Correlation

Considering that correlation is not causation, this section provides the pairwise relation between the codes from mental and design actions. Figure 7 shows the correlation heatmap matrix for each code duration, occurrence, and ADpS. Correlation analysis expresses the inverse or direct proportion between variables. In this experiment, we defined 18 different variables. This section will explain the correlation between the retrieval actions and design actions.

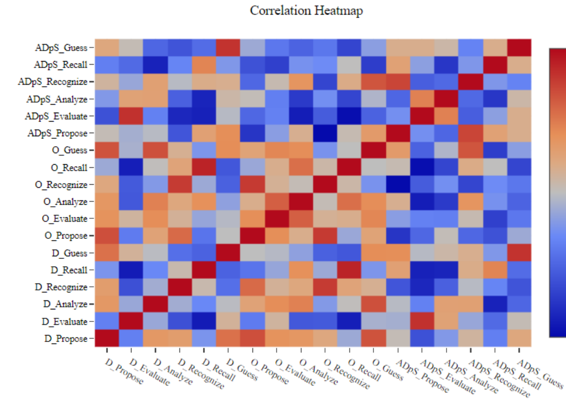

Figure 7. Heatmap Showing Correlation of Codes for Duration, Occurrence, and ADpS Values, with Red Indicating Positive Correlation and Blue Indicating Negative Correlation (by Authors)

As the duration of recall and occurrence of recall increase, the occurrence of analyze and ADpS propose increases, but ADpS of evaluate and analyze decreases. As recall increases, the occurrence of analysis increases, and ADpS evaluation and ADpS analysis decrease. As the ADpS of recall increases, the ADpS proposal increases. As a result of recall action, the need for analysis may arise, and thus, the number of analyses and focus on the proposal will increase. In this relationship, the propose segment durations may increase to understand the compatibility of the retrieved examples with the design solution. The increase in the number of analyses results from controlling the compatibility of the retrieved ideas.

On the other hand, an increase in recall occludes the focus on the evaluation and analysis process, although the number of analyses increases. This occlusion in evaluating and analyzing may increase the possibility of making design errors. Therefore, although recall is important for proposal development, too much recall may increase the probability of error. This situation parallels the literature that too much analogy can cause mistakes in design decisions. Experiments show that, intentionally or not, designers increase the number of analyses to create a strategy for avoiding errors in recall processes.

As explained in section 4.1. recall, analyze, and evaluate actions are successive and cannot occur at the same time, and the realization of one of them may cause the other to occur less. Analyzing and evaluating actions are the supporting actions for recall actions and helps to structure the memory retrieval process properly.

The correlation heatmap shows that recognition duration inversely correlates with the ADpS of the evaluate code, while the number of propose actions directly correlates with recognition occurrences. As in the recall action, recognition action has an inverse relation with ADpS of evaluation. The number of occurrence of recognition has an inverse correlation with ADpS propose and a direct relation with the number of occurence of propose action. During the design process, designers trigger the ideation with recognition, but recognition can still disrupt the designer's focus on a single idea. Each new recognition can trigger a new proposal; due to high number of recognitions and proposals, one cannot focus on one single proposal longer and duration-per-segment decreases for propose code; hence concentrating on a proposal for a long time becomes more difficult. The balance between the recognition and proposal actions may create an efficient design process.

The guess action correlates positively with most design actions, especially all the propose parameters. Designers apply the guess action as an auxiliary action for the design actions. Guess action, feeling-as-knowing, can be a strategic shortcut to propose a new idea. Designers may choose to guess when they make a fast decision on a proposal, and as in the recall process, not to make any mistakes, analyze and evaluate codes are activated to validity check the guessed idea.

On the other hand, the experiment durations can be longer, which can offer more flexibility in the retrieval and design actions for the experiment participants not to be in a hurry and destroy the study's findings. The other important factor to be tested must be a control group, not imposed with the investigation part before the design phase, to fully understand the effects of the retrieval states in the design process.

5. Conclusion

This paper adapts the investigate-and-redesign method while applying the protocol analysis in a quasi-experimental method to examine the nature of the retrieval mechanism throughout the design process. In summary, retrieval actions are inseparable part of the design process. Design actions are focus-demanding actions. On the other hand, retrieval actions are temporary and ephemeral actions in the design process. Recall can be one of the main sources of the propose actions. Recognition can contribute to design process, but if the number of recognition is high than it can be an interfering action in design process. Guess retrieval, feeling-as-knowing action, increases the analysis times due to reliability of the guess retrieval. Occurrence of design actions and retrieval actions shows the strong association among the propose code and recall, recognition, guess codes. Upon reviewing the entire study, it is evident that designers are shifting or modifying their strategies to minimize the error rates in design and accomplish the task in a given time. This process clearly shows the designer's strategy optimization process. We saw that by altering the segment durations, designers adapt their process according to the time limitations. On the other hand, while retrieval actions contribute to design actions, intentionally or not, designers always develop a control strategy to rely on the retrieved information. Design strategy opens an important research question on creating an optimized problem-solving strategy that balances the retrieval and design actions.

All the analysis shows that there is a substantial difference between retrieval actions. Recall is a search mechanism in the memory; recognition is activated when it meets with a clue, and guessing is a shortcut, a feeling-as-knowing act. Guessing is an intuitive decision-making process, and it requires to be controlled. Each retrieval action can play a substantial role in the design decision-making process. Recall, recognition, and guessing have different decision-making processes; respectively, decisions depend on experience, decisions depend on clues, and decisions depend on control. Recall decisions depend on experience strategy may help the designer understand and analyze the problem,

In contrast, developing alternatives may depend on clues, so decisions based on clues and recognition retrieval action can be a good fit. Creative ideas that rely on a control mechanism can be guessing and decision-making based on a control strategy. This study opens this three decision making act as an hypothesis to be tested in the future studies. However, revealing these strategies helps designers understand their retrieval acts and organize their strategy specific to their problem definition. On the other hand, developing design strategies based on different retrieval actions in design education can help novice designers find their design problem-solving path easier.

Despite all the listed findings related to retrieval actions, the generalization of the results becomes statistically questionable due to the limited number of experiments. Hence, the limited sample fails to represent individual and other demographic differences. Moreover, limited sample size results in biased findings. Nevertheless, the study provides valuable insights and opens new hypotheses to be tested about memory retrieval states and the design process, which is the pilot study for future comprehensive studies. For future studies to increase the statistical reliability of the findings and increase the variability of the samples for different demographics, future studies can be conducted with a bigger sample size representing the real world.

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Authors' Contribution

Author 1 and Author 2 contributed equally to the preparation of the survey study, the design of the methodology, the analysis, the preparation of the visuals, and the writing of the manuscript.

The Declaration of Conflict of Interest/ Common Interest

No conflict of interest or common interest has been declared by the authors.

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