FIXATION AND COMMITMENT WHILE DESIGNING AND ITS MEASUREMENT

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Abstract. This paper introduces the notion that fixation and commitment while designing can be measured by studying the protocol of the design session. It is hypothesized that the dynamic entropy of the linkograph of the protocol provides the basis for such a measurement. The hypothesis is empirically tested using a design protocol and the results demonstrate that the dynamic entropy of the design protocol's linkograph may form the basis of the measurement of fixation and commitment.

1. Introduction

There is considerable anecdotal evidence of fixation or functional fixedness while problem solving. Both terms are regularly used interchangeably although there may be subtle differences between. This paper will use the term fixation. Fixation deals with both the inability to see new ways of using objects they are exposed to and the inability to prevent the use of attributes of an object whether appropriate or not. Research into fixation goes back to studies by Duncker (1945), Birch and Rabinowitz (1951) and Adamson (1952).

In designing there appears to be two types of fixation. The first matches the general notion of fixation. The second manifests itself as premature commitment to a particular design solution, observed in both students and practitioners. The designer appears trapped by the characteristics of a possible solution that has been developed or an existing precedent solution. The second may not necessarily be a premature commitment but simply a commitment to a particular set of design decisions that the designer does not change. However, in the design domain, the majority of the discussion of these phenomena is essentially anecdotal and not based on either principled argument or the results of empirical research.

Jansson and Smith (1991) were the first to develop an experimental approach to the problem of fixation in design. They argued that showing designers a picture of a potential design solution to a problem prior to a design session should result in fixation. In effect the picture would act as a precedent, blocking access to other

ways of solving the problem. They also extended the argument about the basis of fixation. They suggested that the process of design involves operating on effectively two types of mental representation of the problem. One representation they refer to as the conceptual space that consists of abstract knowledge about principles, concepts and rules that can be used to solve the problem. The other representation takes the form of particular physical objects and elements that could form the physical realization of a solution to the problem. This representation is referred to as the object space. Jansson and Smith argue that the location of the fixation induced by a pictorial representation is the object space and that innovation is prevented because the designer cannot move to the conceptual space, which is where they consider that innovative changes can occur.

Purcell and Gero carried out a series of experiments that elaborated on fixation in designing, reported in Purcell and Gero (1991), Purcell and Gero (1996) and Purcell et al (1994). They were able to develop a more nuanced understanding of fixation in designing. In their summary they stated:

> "Fixation in the traditional sense may well be found where designers are forced to rely on everyday knowledge. Mechanical engineers become fixated in the traditional sense when the example they are shown embodies typical principles, which are characteristic of the knowledge base of the discipline. ….. Industrial designers appear to show no evidence of fixation under any of the experimental conditions we have employed. However, while showing no evidence of "traditional" fixation, the industrial designers showed no evidence of producing innovative designs using the principle involved in the innovative example. In a sense these groups may have become "fixated" on being different. "Fixation" therefore appears to possibly exist in a number of forms and we as researchers need to be wary of becoming fixated on our conception of what fixation is." (Purcell and Gero 1996)

All of these studies were carried out under controlled, laboratory conditions where the experiments were set up to produce fixation. Fixation was measured by counting attributes of the objects presented and designed. Each design brief, however, results in a different designed object and there is no control object against which to compare. Therefore, such measurements are not possible if we want to measure fixation while designing. This paper presents the beginning of an approach to the measurement of fixation and commitment while designing that does not rely on the specifics of the design brief or on the objects being designed.

2. Fixation and Commitment While Designing

Fixation while designing manifests itself as a potentially premature commitment to a burgeoning solution. Commitment manifests itself as an unchanged design

decision from which other decisions flow, ie, it is like fixation without the notion of the commitment being premature. The first question that arises if this is to be measured is how to locate such behavior. Fixation implies that a commitment has been made at some point in time and that subsequent design issues uniquely relate to that commitment. So what is needed is a method for finding this relation among subsequent design issues.

Protocol analysis (Ericsson and Simon 1983; Van-Someren et al 1994) is one method of capturing design issues while designing (Atman and Bursic 1998; Cross et al 1996; Gero and McNeill 1998; Gero and Tang 2001; McDonnell and Lloyd 2007). The connection between design issues while designing can be found using a linkograph (Goldschmidt 1990). A linkograph is produced by semantically linking individual design issues. Fixation and commitment should manifest in a linkograph as heavy linking from later design issues to a single or small group of earlier design issues. The FBS ontology (Gero 1990) can be used as the basis of coding design issues in a linkograph. This lays the groundwork for the development of the location and measurement of fixation and commitment while designing.

3. Measuring Fixation and Commitment While Designing

Take the verbal protocol of a design session and segment and code it into issues (Kan and Gero 2009). This produces the base information about the design session. Then produce the protocol's linkograph. Fixation and commitment should result in a sharp drop in the information content of the design activity as it now focuses on a single or a small number of issues. Information content can be measured by Shannon entropy (Shannon 1948).

The entropy of the links in a linkograph can be measured. In Shannon's information theory, the amount of information carried by a message or symbol is based on the probability of its outcome. In terms of designing this entropy may be viewed as a measure of the potential of the design activity. In a linkograph the *ON* and *OFF* symbols are used to represent whether two segments are linked or unlinked and *p(ON)* and *p(OFF)* are their probabilities. The entropy, *H,* of a linkograph is calculated using formula (1) (Kan and Gero 2007; Kan et al 2006).

$$H = -p(ON)\log(p(ON)) - p(OFF)\log(p(OFF)) \quad (1)$$

The entropy, *H,* will be zero if *p(ON)* equals 1 or *p(OFF)* equals 1. *H* will have a highest value of 1 when *p(ON)* equals *p(OFF)* equals 0.5. In terms of designing no links between issues implies that the space of issues has no structure and cannot be developed further. If all the issues are linked then no further development is possible. Thus, an entropy of zero matches our conception of zero potential in designing. Low entropies map on to linkographs that are either lightly linked or heavily linked. A lightly linked linkograph implies that the space of issues does not offer many possibilities for development as there are insufficient

links to guide such a development. A heavily linked linkograph implies that the space of issues offers very little opportunity for development since the majority of the issues are already developed.

In order to locate fixation and commitment the concept of dynamic entropy is introduced. Dynamic entropy is based on the entropy of the linkograph measured within a window of a linear adjacent subset of issues of the whole linkograph. It can be produced by running a window of a fixed issue length incrementally moving one segment at a time along the segmented protocol's linkograph, measuring the entropy at each increment. The dynamic entropy of a protocol session gives an indication of the change in potential over time during the design session.

The remainder of the paper presents the results of experiments testing and demonstrating this notion of measuring fixation and commitment in a design session. In what follows the term "fixation" will be used to mean both fixation and commitment as defined above, as the method itself does not distinguish between them.

4. Experiments

The experiment is designed as follows using the method outlined below.

Experiment 1 – Test whether fixation can be measured: take a protocol for a real or simulated design session in which fixation has been observed and measure fixation.

Experiment 2 – Test whether multiple fixations on the same issue can be measured: take the original protocol and introduce additional fixation on the same issue later in the session and measure fixation.

Experiment – 3 Test whether multiple fixations on different issues can be measured: take the original protocol and introduce additional fixation on a different issue later in the session and measure fixation.

The method used in this experiment is:

1. segment/code a design protocol using the FBS ontology
2. generate its linkograph
3. produce its dynamic entropy
4. determine if there are sharp drops in entropy to determine fixation
5. locate the sharp drops in entropy to locate fixation
6. measure the extent of the entropy reduction to measure the extent of the fixation
7. check in the protocol whether fixation can be observed qualitatively and whether it matches the location of the measured fixation.

5. Results

Experiment 1

Figure 1 shows the linkograph, produced from segments coded using the FBS ontology, of a session that exhibits fixation. The linkograph has 116 segments.

Fixation occurred on the issue at segment 55. Figure 2 show the section of the linkograph that commences with segment 55. The unique structure of the linkograph claimed to be associated with fixation can be observed in Figure 2 in the links emanating from the issue at segment 55.

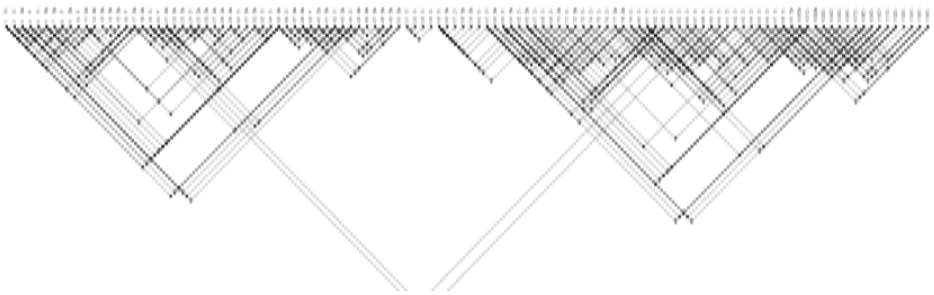

Figure 1. Linkograph of design session exhibiting fixation

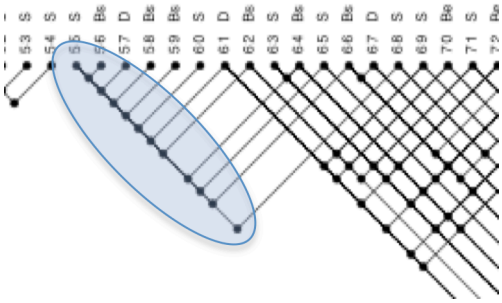

Figure 2. Subset of linkograph of design showing where fixation is located

Figure 3 show its dynamic entropy produced by using a window of width 12 , ie, 10% of the length of the protocol.

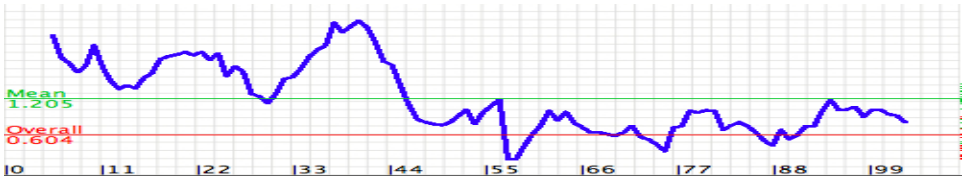

Figure 3. The dynamic entropy of the linkograph in Figure 1. The horizontal axis lists segment numbers in sequential order and the vertical axis is entropy, increasing along the vertical axis. The absolute values of the entropy are not of interest, only their relative values.

The rapid drop in entropy to a low value was measured centering around segments 56-58 and is of a short duration. This matches the expectation based on the claim that fixation causes a sharp drop in entropy.

Experiment 2

In this experiment there is the initial fixation and an additional fixation later on the same issue with a longer duration. Figure 4 show its dynamic entropy produced by using a window of width 12 , ie, 10% of the length of the protocol.

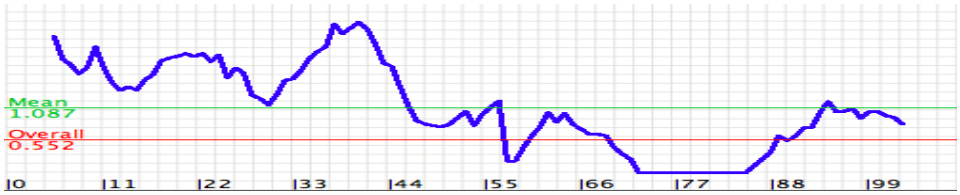

Figure 4. The dynamic entropy for the initial and additional later fixation on the same issue. The horizontal axis lists segment numbers in sequential order and the vertical axis is entropy.

There are two rapid drops in entropy in Figure 4. The first is of a short duration and the second of a longer duration. This matches the expectation based on the claim that fixation causes a sharp drop in entropy. The drop is exhibited even when there are two fixations on the same issue.

Experiment 3

In this experiment there is the initial fixation and an additional fixation on a different issue of a longer duration than the initial fixation but of a shorter duration than the additional fixation in Experiment 2. Figure 5 show its dynamic entropy produced by using a window of width 12 , ie, 10% of the length of the protocol.

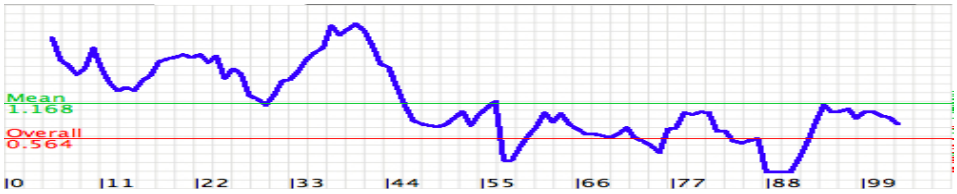

Figure 5. The dynamic entropy for the initial fixation and an additional later fixation on a different issue. The horizontal axis lists segment numbers in sequential order and the vertical axis is entropy.

There are two rapid drops in entropy in Figure 5. The first is of a short duration and the second of a longer duration. This matches the expectation based on the claim that fixation causes a sharp drop in entropy. The drop is exhibited even when there are two fixations on two different issues.

6. Conclusions

Fixation is a behavior that that takes the form of a commitment to a single or set of issues that affects later issues and can occur while designing. It has been qualitatively observed. Experiments have shown that designers exhibit fixation. These experiments were of the input-output kind and the effects of fixation were measured in the resulting designs. In order to measure fixation in the process of designing it has been hypothesized that fixation can be measured from the protocol of the design session by calculating the dynamic entropy of the linkograph of the session's protocol. The experiments reported in this paper provide empirical evidence to support the hypothesis. More research is needed before the hypothesis can be adequately confirmed as the results are from a case study only.

Assuming that the hypothesis is confirmed and we can measure fixation in this manner then methods for detailed measurements to further characterize fixation will need to be developed. The relationship of fixation with design performance will then be able to explored in more detail and techniques to remove or enhance fixation developed.

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