USING REPERTORY GRIDS TO MEASURE CHANGES IN RISK-TAKING BEHAVIOR

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This paper develops an experimental approach to understanding how construction workers modify their risk taking behavior when safety schemes are implemented. The study takes a qualitative approach using (1) repertory grid techniques to map attitudinal change and (2) navigable movies to reproduce the experience of surrogate travel. Hazard categories emerged from the data to produce a framework with which to explain underlying compensatory phenomena. Results show that construction workers do modify their risk taking behavior after safety systems are implemented. However, this does not necessarily result in a safer approach to work hazards.

Keywords: Construction safety; hazard perception; panoramic VR.

1. Introduction

The UK construction industry is looking at safety with a new urgency. Despite attempts to foster safe working practices with the implementation of the Construction Design and Management Regulations (CDM), aimed at helping to reduce accidents, few signs of improvement have been seen since then. The CDM regulations were introduced in 1994 to co-ordinate the management of health and safety through the design and construction process (Williams, 1996). Despite this, the number of construction accidents continues to rise (H&SE, 1999).

This paper suggests that the industry could improve its safety performance by looking more closely at individual behavior rather than summary statistics on accident aetiology (Adam, 1999). In this way, policy makers and other key people involved in construction safety such as training establishments, would have other ways of understanding the root causes of accidents.

The paper presents a case for understanding how workers modify their behavior when safety systems are implemented. The premise is that a worker is less aware of hazard signals when safety measures are undertaken, with the consequence that
the introduction of a safety schemes may not improve construction safety due to
the ensuing compensatory behavioral changes.

The theory behind this hypothesis, known as risk homeostatic theory (RHT),
was first proposed by Gerald Wilde in the mid 1980s when assessing the impact of
the seat belt legislation on the reduction of car accidents (Yates, 1992).

Wilde’s theory is based on a cost-benefit model. He studied how people modify
their hazard perception when safety systems are implemented. This process is well
described in his theory of risk compensation and risk homeostasis, which states that
people adjust their risk acceptance decisions and their risk taking behavior towards
the target level of perceived risk. People will behave more cautiously and accept
fewer risks when they feel threatened, conversely, they will behave more daringly
and accept higher levels of risk when they feel safe and secure (Adams, 1988).

The technique used to elicit hazard constructs for this study is based on the
Repertory Grid (Bannister, 1968) method. The technique relies on semi-structured
interviews where participants discuss specific stimuli such as objects, people, ac-
tions or places. In this case, such elements comprise simulated scenarios depicting
the participant’s workplace. By comparing and differentiating these elements, it is
possible to map personal constructs. The Repertory Grid method is founded on the
theory of Personal Construct Psychology (PCP) developed by George Kelly (1959).
A comprehensive explanation of Repertory Grid is beyond the scope of this paper,
yet it will be introduced to illustrate how a technique that was originally developed
for clinical use has been validated in other fields including ergonomics, management
and education.

In this paper, the procedure of constructs elicitation will be described. Construct
are concepts defined in participants own words. Groups of constructs form individual
repertory grids. These grids are represented as matrix tables that contain:

- Elements are the presented stimuli for discussion
- Constructs are concepts derived by participants
- Ratings are the hierarchical values assigned by the participant.

Constructs represent qualitative properties and the ratings are non-parametric
values, which aid in defining spatial relations between the parts of a table because
of such such hierachical trees of the relation between elements and constructs. Al-
though grids represent qualitative data, they can be analyzed statistically. In this
way, it is possible to find relations between elements within a grid and links between
grids (Bell, 1999). In the Grid Analysis, similarities and differences between Grids
were calculated (Bell, 2000) and patterns of risk taking attitudes were revealed.

The result of this paper contributes to the validation of Wilde’s risk homeostasis
theory (Trimpop, 1994) in the context of construction. The authors argue that RHT
should have a bearing on the design and implementation of safety procedures such
as legislation, training and management in the construction industry.
2. Approaches to Risk Perception

Risk perception deals with the understanding of perceptual realities and indicators of hazards, i.e. the perception of objects, sounds, odours, or tactile sensations. Fire, heights, moving objects, loud noise and acidic smells are some examples of the more obvious hazards which workers normally interpret as common sense. However, most industrial hazards are hidden to the naked eye (Eysenck, 1997).

In risk perception, two psychological processes may be distinguished: hazard perception and risk assessment. Lowrance (1976) defines the information processed during the accomplishment of a task in terms of the following two components: (1) the information required for executing a task (hazard perception) and (2) the information required to keep existing risks under control (risk assessment). For instance, when a construction worker is on the top of a ladder drilling holes in a wall, he has to simultaneously keep balance and automatically coordinate his body-hand movements. Hazard perception is crucial to coordinating body movement to keep dangers under control, whereas conscious risk assessment plays only a minor role, if any (Lowrance, 1976).

A hazard represents a source of energy with the potential of causing immediate injury to personnel and damage to equipment, environment or structure. A temporal characteristic of hazardous energy is that it has an immediate effect on the person. This contrasts with other types of injurious situations such as exposure to certain toxic substances, bad posture, or the effects of the sun which delay their effects over months or even years. Naomi Holmes (1988) studied the perceptual difference between these two areas with groups of construction workers in Australia. She found that some hazards were imperceptible at a given time. An example of this is the exposure to the sun, which can badly harm the skin.

Other hazardous situations can be defined as those that have attributes of novelty, abruptness and high intensity in a situation where fear stimuli appear. The sudden occurrence of loud noise, loss of balance, and objects rapidly increasing in size as they approach are fear stimuli, prompting automatic responses such as withdrawing a hand or jumping (MacGill, 1986). Behavioral psychological research uses psychometric methods to measure reaction times to given stimuli as a way to measure and eventually to predict behavior or hazard response (Blackwell, 1997). In contrast to this, we take a cognitive approach to the study of risk perception.

Cognition stands by the principle that hazards and toxic substances are not always directly perceptible to the human senses, but are inferred from cognitive indicators. Neisser (1967) defines cognition as the processes by which the sensory input is transformed, reduced, elaborated, stored and recovered. In the context of construction work, such indicators can be colors on cables to detect electric currents or a type of material to detect a fragile roof. The presence of potential hazards must be signalled by knowledge or devices that translate such a presence into something which is recognizable, e.g. electrical currents can be perceived with the help of a current checking device.
Table 1. Detection and perception of hazard-indicators in industry (Ruppert, 1993).

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Hazard perception process</th>
</tr>
</thead>
<tbody>
<tr>
<td>80.0%</td>
<td>Rated total</td>
</tr>
<tr>
<td>77.3%</td>
<td>Visual recognition</td>
</tr>
<tr>
<td>63.0%</td>
<td>Selective attention</td>
</tr>
<tr>
<td>57.5%</td>
<td>Division of attention</td>
</tr>
<tr>
<td>56.3%</td>
<td>Rapid identification and responsiveness</td>
</tr>
<tr>
<td>51.5%</td>
<td>Perception of incessant hazards</td>
</tr>
<tr>
<td>44.2%</td>
<td>Observation and maintenance of distance</td>
</tr>
<tr>
<td>28.0%</td>
<td>Detection of potentially dangerous objects</td>
</tr>
<tr>
<td>25.0%</td>
<td>Vigilance</td>
</tr>
<tr>
<td>21.2%</td>
<td>Auditory detection</td>
</tr>
<tr>
<td>19.9%</td>
<td>Recognition of changing danger zones</td>
</tr>
<tr>
<td>17.9%</td>
<td>Direct attention</td>
</tr>
<tr>
<td>15.9%</td>
<td>Auditory recognition of warnings</td>
</tr>
<tr>
<td>7.3%</td>
<td>Visual recognition of warnings</td>
</tr>
</tbody>
</table>

Table 1 illustrates how vision works at various cognitive levels in the hazard perception process. Various situations can demand different levels of knowledge to detect potential hazards. Visualizing a hazard does not mean that we have correctly assessed the potential risk in dealing with it. Thus, the difference between visual recognition of warnings (7.3%) and visual recognition (77.3%). For example, a worker can see that he is walking on a roof but he chooses to ignore the possibility that such a roof could be fragile. Hoyos (1993) found that a person’s knowledge of hazards is acquired by experience or deduced from one’s knowledge of the common principles of causality. Ruppert (1993) investigated an iron and steel factory and found that from 2,230 hazard indicators named by 138 workers, only 42% were perceptible by the human senses. Perception of hazards, in the sense of direct perception of shape, color, loudness, odours and vibrations, is also restricted by the limitations of the perceptual senses, which can be temporarily impaired due to fatigue, illness, alcohol or drugs. Adding environmental factors such as fog, glare, and noise can put heavy stress on perception, and dangers can fail to be detected because of distractions or insufficient alertness.

On accepting risks, research shows that people are more likely to underestimate high risks if they have been exposed for an extended period, such as living below a power dam or in earthquake zones, or having high risk jobs, such as in construction (Zimolong, 1985). People use their personal knowledge and experience about a particular risk, tending to accept more well-defined risks whilst previously unknown risks are judged more by levels of severity. This suggests that an external environment will certainly affect the perception of hazards; furthermore, people seem to judge human-made risks very differently from natural risks, accepting natural ones more readily than self-constructed, human-made risks. Finally, it is hard to
determine what risks have been consciously accepted, as many people are seemingly unaware of many risks surrounding them (Arabie, 1988).

Even if people are aware of the risks surrounding them, the problem of accepting and adapting occurs. This process is well described in risk compensation and risk homeostasis theory (Wilde, 1988; Yates, 1992), which states that people adjust their risk acceptance decision and their risk taking behavior towards their target level of perceived risk. Risk homeostasis theory was born in the mid 1980s it has been applied in the context of road accidents especially with car drivers (McKenna, 1985; Adams, 1988; Trimpop, 1994) and other fields such as in the mining industry the risk homeostatic phenomena was also investigated (Wilde, 1997). If proved true in the context of construction this compensatory model will impact on legislation, training and ergonomics.

3. Methodology

Personal construct psychology is a theory of individual and group psychological and social processes that takes a constructivist position in modelling cognition (Shaw, 1992). It provides a fundamental framework for both theoretical and applied studies of knowledge acquisition, attitude measurement, personality and cognitive mapping. George Kelly (1955) conceived this theory, explaining that a person is capable of applying alternative constructions or meanings to any events in the past, present or future. The theory rejects the existing schism between affect, cognition, and action present in social psychology since the early attitudinal theories of George Allport (Allport, 1935; Rosenberg, 1960). It recommends that these three parts be construed together to develop a fuller understanding of human behavior, giving a holistic understanding on how we interpret reality.

It can be said that Kelly’s fundamental postulate is that a person perceives the world in terms of whatever meanings this person applies to it. Having the freedom to make meaning of our realities means that perception depends not only on the presented stimulus but also on internal hypotheses expectation, and stored knowledge. Kelly’s postulate takes the metaphor of “man — the scientist”, saying that we all are constantly exploring possible outcomes from our daily behavior, this is, we are not only constantly perceiving reality but also making predictions, anticipating events, and ultimately our own behavioral outcome. Behaviorists would criticize Kelly’s approach pointing out that there are no links between attitudes and behavior, explaining that attitudes are not always reflected in human performance, and it is behavior that is directly relevant to accident causation and prevention. Nevertheless, we assume that to change behavior, if necessary, one must change attitudes, and one cannot reliably change attitudes without knowing what they are.

Attitudes can be read in personal construct systems and can be measured using a variety of methods. The one adopted for this study is called Repertory Grid, which uses intuitions underlying personal construct psychology. Repertory Grid facilitates the elicitation of personal constructs in a systematic way, and enables comparison
between construct systems. Grids are generally formed by *elements, constructs* and *ratings*. This study focuses on interpreting and comparing personal grids elicited in a lineal study. Each grid snapshots safety attitudes at work and they work as a catalyst in data elicitation. Results are based on the assumption that emerging differences between grids indicate how, or if, workers modify their risk taking behavior.

The elicitation of repertory grids is based on a *conversational* technique. For this reason, they can be elicited manually or with the aid of a PC to facilitate the administration process. There are a variety of programs to elicit and analyze grid data, which all provide a basis for approximating intentional distinctions, or constructs, when applied to elements in a particular subject. The distinctions made by the same individual at different times or by two or more individuals in a same session can be measured and compared. These two relations of similarity between distinctions and between terminologies give rise to a four-way classification of constructs (Shaw, 1992). Figure 1 shows the model of construct systems.

- Consensus arises if the construct systems assign the same term to the same distinction.
- Conflict arises if the systems assign the same term to different distinctions.
- Correspondence arises if the systems assign different terms to the same distinction.
- Contrast arises if the systems assign different terms to different distinctions.

The usual technique for eliciting constructs is to have two people negotiating common sets of elements, characterizing a domain such as safety at work. Each construct has two ends, the emergent pole and the implicit pole. This is because bi-polar constructs help to better show our understanding of things. Once a series of constructs are elicited and rated, grid comparison is possible; this comparison of grids allows consensus, conflict, correspondence and contrast to be modeled.
4. The Tool

Many different visualization tools have been used to investigate perception and attitudes. As computer visualization has advantages and drawbacks, the decision to use them depends on the research issues to be investigated, the sophistication of the system and on funds available. This is to say any one study could use different tools and different techniques according to the purpose of the study.

Multimedia and semi-immersive environments are increasingly being used in psychological experiments. For instance, computer images and animation have been used to test theories of perception and cognition. Stappers and Waller (1998) tested people’s ability to use the free fall of computer animated objects as a scale referent in a 2D display, whilst Mayer and Sims (1994) used computer generated animation to investigate the dual-coding theory of multimedia learning.

In behavioral studies, Winer et al. (1996) used computer-animated techniques to investigate the beliefs amongst children and adults concerning the act of seeing. In numerous cases, these visualization techniques have improved upon previous photographic and computational techniques. Other simulators would include Tuophy (1996) who used a video simulator technique to analyze the behavior of pre-drivers. West (1996) used computer simulator techniques to study response on driving tasks, as did McKenna and Horswill (1994). Results from previous studies have directly affected driving legislation, and road safety, e.g. training and licensing, location of traffic signs, safety campaigns, and road designs.

For this study, Panoramic VR technology was used as the visualization tool. This media is also known as still video or navigable movies. Panoramic VR is based on photographic methods. Various authoring packages are currently available; the three most popular are Quick Time VR Authoring Studio®, VR Toolbox® and Realviz®. Other options include Java authoring script and plug-ins for Adobe Photoshop® such as Helmut Dersch’s Panorama Tools shareware. With any of these packages it is possible to author interactive walkthroughs of buildings with ease. For this study scenarios were embedded in Filemaker® to archive and prompt the virtual movies (see Fig. 2). In this way, participants could elicit constructs in a game environment. The Rep-Grid software prompts triads of movies of site under scrutiny. The virtual movies (or scene nodes) act as elements that can be compared and contrasted. These answers are then written down in the given fields.

Although Rep-Grid software was developed in the 80’s (see Shaw, 1995) its graphical possibilities and ease of use keeps it in the lead if compared with newer packages which are more concern with data analysis. Rep-grid gives instant feedback on grid results in a graphical manner. In this way, participant and interviewee can discuss results and modify them if necessary. Amongst the graphics prompted are: structured repertory grids, cluster analysis, dendograms, principal component analysis and socio maps.

Panoramic VR provided some of the following benefits for this investigation:
It is a friendly technology
- It presents an alternative to surrogate travel
- It avoids site disruption
- It provides a safe environment for the investigation
- It allows access to cases that would otherwise be difficult to experience.

5. Procedure

Firstly, the participant had to go through the complete set of virtual scenarios merged in a single walkthrough (see priming participants in Fig. 2). An adjacent window included a birds-eye navigation map with a rotating arrow indicating location and direction of the scenes as they were explored. On a second stage, triads of scenarios were prompted as proceeding with the triadic elicitation, constructs.

Fig. 2. Interface and display on the analysis of various working scenarios.
emerged and fields were filled. In the final stage, participants had to establish a hierarchical relationship between the scenes and the constructs with a numeric scale from 1 to 5.

5.1. **Preparation**

Eight construction workers with a minimum of two years of work experience in construction were invited to participate in the study, all of whom were familiar with the site of study (a 35,000 ft\(^2\) new office building). Panellists were asked whether or not they could spare an hour in an interview to interact with multimedia games. The nature and procedure of the research was explained and the study carried out on an individual basis.

5.2. **Construct elicitation**

Participants were prompted with triads of site locations at the time. They were asked to name one aspect of safety at work on two locations and a different one on the third location. Details of the responses were written in specific fields. This process was repeated in various combinations until all the scenarios were clearly differentiated.

5.3. **Element rating**

A third stage is when all the elements were rated from 1 to 5 in their relation to the bipolar constructs. In this case, the elements represented by 7 scenes and the 12 elicited constructs formed a matrix table of 7 \(\times\) 12. Grid cells show the respective ratings for the elements and constructs. Grids can be analyzed individually or compared with other grids to define their links and similarities. Rated grids indicate how participants relate working scenarios with their construct system. Differences between grids would indicate changes in these relations.

For the comparative stage the original grid was duplicated twice but without ratings. In this way, each grid was rated a second and a third time presenting a case for comparison. By the end of the study, each panellist had three grids. Each grid represented different times and working conditions. Grid 1 represents the time before the safety system or measure was implemented. Grid 2 represents the time immediately after the measure was implemented. Grid 3 represents the present time, i.e. the time since the measure was implemented — this was the original grid. Note that the pre-implementation grid (Grid. 1), and post-implementation grid (Grid. 2) were rated retrospectively. This is because participants were asked to remember a recent safety measure taken by site management (see Fig. 3).

Topics on grid discussions included: training sessions, protective gear, or new site devices. Then a participant was asked to rate his grid by thinking how he would assess the various places in terms of danger, that is: before the event and after the event.
The relationship between constructs and elements as shown in Fig. 4 can be viewed as cluster blocks, these are the shadowed areas shown at three levels (clear, dotted and dark). They indicate how the elements of a repertory grid cluster by areas on both: the $x$ and $y$ axes. This presents a spatial relationship of an individual’s construct system, facilitating a tool to give meaning to a particular session or discussion to both participant and researcher.
Cluster groups also help to find qualitative similarities between grid tables. This is because relations between grid components are ordered and presented in a simple manner. If we look at the grid overleaf it is possible to spot two main cluster groups: the dark one which is to the top right and the one which is to the bottom left, but at the same time these groups are fragmented (e.g. the dark at the lower left side or the clear area at the bottom right). These type of cluster relations are subject to scrutiny and further discussion with the participant, as the most important contribution of this graphic technique is that it informs researcher and participants to the results before the session is finished. As the repertory grid is not a test but a method to structure conversation and thinking, any changes may be made aloud at any point of the elicitation process.

Dendograms, are the tree-shaped diagrams on the left and the bottom of the grid. They indicate the hierarchical relationship between constructs or between elements in a construct system. The further they branch-out (e.g. towards 100% on the adjacent scale) the closer is the relation. In this case, the safety report/signage and the work alone/group are the closest pair of constructs in the grid. It is possible to device three less similar groups: group a: (c.2, c.4, c.12,); group b: (c.11, c.5, c.7, c.6, c.8); and group c: (c.1, c.9, c.3). Note that as c.10 stands alone, it implies a weak relation with the rest of the constructs. Each of the previous situations should provide a reason for further discussion such as “Why does being struck by a vehicle represent a different sort of hazard” or “What similarities do you find between visibility of signage and working alone/working with others?”

Figure 5 shows comparative figures between grid results. Such results reveal how a personal construct systems changes over time implying that workers modify their views on safety as working conditions change. However, these behavioral modifications do not necessarily mean a better approach to work hazards. When safety devices are implemented, workers can become overconfident and are thus willing
to take higher risks. If we remember that grid three (G3) equals the present time, grid one (G1) equals the time before the safety measure was implemented and the grid two (G2) corresponds to the time immediately after the safety measures were implemented, it is possible to appreciate the results in terms of changing behavior.

The assumption is that (G2) represents the best situation in terms of a safe environment, because it represents the time when measures had just been implemented. Worker’s changes are represented by the differences between (G1) and (G2). As (G3) represents the present time it was expected to have a much higher percentage in similarity with (G2), however, it was found that with over 80% of commonality with (G1). This implies a less responsive behavior towards site safety.

6. Concluding Remarks

The paper attempts to raise the issue of compensatory behavioral phenomena when safety systems are implemented. The rational behind this assumption is that workers change their behavior to changing circumstances in order to keep the objective risk essentially constant, i.e. if a building site is safer, particular workers will become over confident in the way they go about their work, allowing more chances for accidents. Unless worker’s values are modified, they will continue to take risks even if a site is perceived to be a “safe” or a “safer site”. This presents a case to predict the effect of a safety improvement from the mechanical or managerial viewpoint in that if behavioral responses are not addressed accordingly, the effects of the effort will be diminished.

This situation highlights only some of the difficulties that construction professionals face when implementing safety systems or procedures such as protective gear, training programmes or management without the workers offsetting the possible safety benefit by some personal benefit, such as increased confidence, comfort, decreased attention or other more risky behavior. This means that whatever changes are made, workers will simply change their behavior in order to return to the level of risk that prevailed before the improvement was introduced. Although risk homeostasis theory has proved extremely controversial and has not yet been validated, it has direct implications for construction because if proved true any attempt to improve safety by engineering might not be as effective as expected. References were cited to illustrate the theory and to show evidence from other fields such as transport.

6.1. Tool assessment

Although offering the potential to visit remote sites, specific limitations on the use of this Panoramic VR have been identified, in particular:

- There is a danger of information overload on the participant
- Results can be biased by visual perceptive ambiguities
- It presents a shortage of other vital perceptual cues.
The merger of virtual databases with the repertory grid program is inevitably imperfect in giving representations of the real environment in part because of the impracticalities of capturing all possible settings, and in part because other vital perceptual cues are missing, including touch, smell, and kinetics. However, it was found that this is not necessarily a disadvantage since rich visual cues present appropriate stimuli to recall experiences — also known as stimulated recall.

In order to effectively use this technology, a good experimental design is firstly needed from which it is possible to develop a meaningful walkthrough in a systematic manner. The complete process would include: planning, image capturing, and authoring a walkthrough.

The use of the grid technique demands empathetic interaction with participants as participant and researcher would have to discuss issues throughout the session. This means that it is necessary to have good interviewing skills when proceeding with the work. The use of navigable movies with the rep-grid software bring visual stimuli and easy administration to the study sessions, but simply giving participants a simulation tool and expecting them to provide answers is not sufficient.

6.2. Further steps

The study suggests that implementation of motivational models is the way forward to improve safety in the construction industry. A way to approach this is by looking more closely into education, training and workers self-development. This will help to re-adjust their targeted level of risk-taking behavior. A possible way to do this is by increasing the value of safe behavior, which may increase the motivation to accept the less dangerous alternative. This approach aims at changing individual values, norms and beliefs to motivate alternative risk acceptance. It is concluded that attitudes can be changed and a clear example for this exists in the efforts to change bad driving habits, such as drinking and driving.

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