

Exploring representation: A semiotic approach to understanding the image as a carrier of design meaning in a collective design context.

by

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of the requirements for the degree of Doctor of Philosophy.*

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Author's Declaration

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. I give consent to this copy of my thesis, when deposited in the University Library, being made available for loan and photocopying subject to the provisions of the Copyright Act 1968.

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Glossary of Terms

BIM	Building Information Modelling
CAD	Computer Aided Design
CI	Collective Intelligence
CD	Collective Design
CSCW	Computer Supported Collaborative Work
ODE	Online Design Environment
HREC	Human Research Ethics Committee
Sg	Semiotics in a general context
Sd ⁽¹⁾	Semiotics in the first design context
Sd ⁽²⁾	Semiotics in the second design context
HIT	Human Intelligence Tasks
WWW	World Wide Web
VDS	Virtual Design Studios

Abstract

Collective design has been investigated increasingly in the design research community in recent years. Researchers so far have provided conceptual models for design environments and looked to crowdsourcing for insights into motivation, communication and representation. However, with motivation and communication well explored, there is a lack of empirical evidence to support the understanding of how representations might be used in a collective context to convey meaningful design-related content.

This research aims to explore representational use under collective conditions. To achieve this, a study was conducted to compare an expert group of designers in an online design environment (ODE) with a small crowd consisting of 18 participants. Both groups were required to engage with the same design task over a two week open design session in each environment. The ODE was used to collect data during the experiment. By employing a semiotic coding scheme, specifically developed for this study, the collected data was coded and analysed using comparative, and cumulative comparative, analysis methods. The differences were identified through the comparison of experts' and crowd's behaviour in the ODE. From these results, it can be suggested that representation plays an important role in catalysing and supporting design activity in each group, both with unique characteristics within the ODE.

This study reveals that when presented with a design 'problem', and within the collective conditions established for this study, it was observed that human reasoning processes can actively participate as the creative agent in a collective system. In the openly shared collective context of this study the representation was found to be an integral component in the crowd's shared design reasoning processes. These processes consisted of expressed intuition, trains of thought, inquiries, questions and arguments. As such, this study might aid the development of collective mechanisms to support and capture these reasoning processes. Therefore, the outcome of this study may prove beneficial

not only for design educators and design researchers but also for World Wide Web (WWW) and software developers.

Chapter 1: Introduction

This thesis focuses on depictive representations which, according to Visser's (2007) description, are neither complete nor objective. The representation is simply a construction used for some purposes, under certain conditions, by certain people, in certain situations, and may be found useful, not true or false (Bannon, 1995; Visser, 2007). Representations are built or used to make things *"visible so that they can be seen, talked about, and potentially, manipulated"* (Suchman, qtd by Visser, 2007, p. 13). Humans are essentially a symbolic species (Deacon, 1997). Symbolisation is the "most characteristic mental trait of [humans]" (Langer, qtd by DeLoache, Pierroustakos, & Uttal, 2003). "Just as the emergence of the symbolic capacity in the course of evolution irrevocably transformed the human species, so too does the development of symbolic functioning within the cultures and societies in which humans co-exist" (DeLoache, Pierroustakos, & Uttal, 2003, p. 114). The question of the development of the connection between the human being and the symbolic image is difficult to answer definitively. What is known, is that at some point in our history, an event occurred which archaeologists refer to as the 'creative explosion' (Spivey, 2005). The earliest known examples of this creative explosion are found in the Australian Aboriginal rock art at Ubirr (Arnhem Land, Northern Australia) and the Chauvet cave paintings in France (both estimated to be c.30,000 BCE) (Chippendale & Taçon, 1999; Valladas, Tisnerat-Laborde, Cachier, Arnold, De Quiros, Cabrera-Valdes, Moure-Romanillo, 2001). Although not as old some of the best preserved examples of this creative explosion are found at Lascaux where approximately 17,000 years ago humans were using cave walls as a canvas for the creation of images. From Ubirr to Chauvet to Lascaux these images would often symbolically represent abstract shapes and animals found in the real world around them. Spivey (2005) argued that these early abstract cave paintings were the product of various group's of Shamans expressing the content of their trance-induced visions. Having expressed these visions as images, they not only invented art itself, but were also sharing the

representational meme with the group. In doing so, the image took on a culturally relevant and shared meaning (Spivey, 2005).

Today, representations are communicated globally in ways our ancient ancestors could not have imagined (Spivey, 2005), but the role of representations has not changed. The representation still carries a culturally relevant meaning, rendering the transformation from a geological backdrop to a digital backdrop; a purely arbitrary shift of circumstance. Today, we no longer have to search for shamanic imagery. By default, we are immersed in symbolic imagery from the moment we awaken via our digital surroundings; the clock, the mobile phone, the morning news, the computer. Surrounded by representations from a young age, we developed a pictorial competence enabling us to enact an interpretive process by which meaning is gained from an image when we observe it (DeLoache, Pierroutsakos, & Uttal, 2003). These images are no longer on the cave wall, but in newspapers, in magazines, in movies, on our mobile devices or on the Internet where there are over 2.8 billion individual global users, yet who simultaneously engage in the same interpretative process as our cave-dwelling ancestors. From the French caves at Lascaux where the Shamans drew the earliest recorded abstract symbols and animals, to the digitally mediated world that seamlessly integrates graphic representations into our lives today; the function of the representation has remained historically consistent. The purpose of the representation is to help share and provide meaning through symbolic, lifelike and referential imagery that depicts or represents to us things that exist, do not exist, or could exist in the world around us.

The visibility of the shared representation was no less important for the early cave painters because it allowed the Shaman to express the content of his vision and contribute to collectively shared group knowledge (Spivey, 2005). Today for the designer, the sketch or model fulfils much the same role because it is the shared representation central to the designer's method of expressing his/her intentions in terms of taking an idea and bringing it into existence. This highlights a persistent commonly shared human ability: that as human beings

we have always demonstrated a natural competence to use representations in order to make visible, or manipulate, the things we want ourselves and other people to see. For the designer, as with the earlier cave painters, communicating things that do not exist, to other people, is a key feature of their role within the culture of their society. Today, the WWW provides the opportunity for anyone with access to create visually rich media content that rapidly transmits culturally relevant meaning on a truly globally, collective scale (Levy, 1997). In the wake of the convergence of web-based users, who are increasingly familiar with generating and sharing meaningful, representational content on a globally collective scale, it is logical to present a discourse centred on imagery in the search for insights into design and how it might arise under the collective conditions presented by the WWW.

The development of society and culture witnessed growth in the representational complexity of the sign systems that allowed for the communication and expression of ideas-based information. From the cave and rock walls used to communicate symbolic imagery to the immediate group, to the stone tablets carved with complex combinations of coded symbols that made up early Sumerian and Egyptian writing systems, to the explosion of Renaissance art that iconically and symbolically represented the local noblemen and biblical passages alike, the craftspeople involved were not specifically identified as designers. Instead, their work was considered to be the vernacular product of skilled craftsmen in a society where there was no clear distinction between professional and amateur design ability (Cross, 2006). Only since the industrial revolution has the distinction of being a professional designer emerged as an identifiable specialist, or expert, separate from the vernacular craftsmen (Cross, 2006). With this specialisation, a particular way of communicating with the representative image was developed. Effective communication clarity is paramount to a designer. Over time, designers have developed and refined a highly sophisticated set of sign-based systems allowing them to use representations to accurately express a design meaning regarding objects that do not exist (Arias, Eden, & Fischer, 1997; Ashwin, 1984; Goldschmidt, 1991, 2004; Schön, 1983; Suwa & Tversky, 1997). The designer

will use a wide array of expressive representational methods to keep track of, serve as 'objects' to think with, enable social communication regarding, and capture essential elements of, the predicted design outcome (Arias, Eden, & Fischer, 1997). With a conventionalised use of imagery, the designer is able to make visible their ideas so that, in Schön's (1983) terms, they can engage in a shared conversation and advance their own and the group's design activity (Visser, 2007). Much of the understanding around how design information is passed from person to person is obtained through interpreting the meaning embedded in the often-symbolic representations used by designers. As a result, this places the experts and their use of the representation at the heart of many discourses where design, as an activity, is the central focus.

Beyond professionalised design and its specialised marginalisation of representational conventions, it is hard to ignore that today the Internet is allowing the memetic representation to be used more widely than any other time in history, for transmitting meaningful information. In comparison to the relatively small expert design team the decentralised structure of the WWW is allowing much greater number of individuals to engage with, and actively create or design, their own media-rich representational content; in turn enabling them to communicate, collaborate, share knowledge (regardless of quality), and mobilise in real time in ways that have historically never been collectively possible (Berners-Lee, 2010; Levy, 1997; Malone, 2004). Increasingly complex sign systems are emerging from the freedom of expression of ideas, imagery and important concepts via the Internet. The WWW has replaced the cave wall, and no longer is it the single Shaman, but millions of users who now express themselves collectively using the same inherent capability that existed long before the advent of the expert designer. That same inherent ability can be traced back to circa 30,000 years ago at the French caves at Lascaux and the 11,000 year old carved stone walls of Göbekli Tepi (Turkey). And that is the timeless ability to express ourselves and our meaning to others through the use of representations. It is the sum total of these 2.8 billion WWW users who collectively 'know something' and possess the inherent capability to design and share meaningful information—no longer via the rock wall—but via

representations that exist and can be interacted with in real time over the web, which offers a unique opportunity, not only to reconsider the validity of the comparison between the vernacular and an expert, but more importantly, to “reconsider design as a role of web based collective intelligence” (Maher, Paulini & Murty, 2010).

The connection between design and collective intelligence (CI) is gaining momentum in the design community as many new online platforms support novel ways of allowing medium sized groups, and even larger crowds of motivated online people, to contribute toward solving complex problems (Paulini, Murty, & Maher, 2011).

Current research into collectively oriented design has emerged from: J. R. Licklider’s work (1942 to 1968) at the Advanced Research Projects Agency (ARPA); Bush’s Memex studies in the 1940s; and, Douglas C Engelbert’s (1968) demonstration in the augmentation of the interactions between computers and humans. It was Engelbert’s (1968) demonstrations that were to provide a glimpse of the forerunner of many programs that support computer supported collaborative work (CSCW) today (Myers, 1998). Today CSCW is a complex and multidisciplinary field encompassing artificial intelligence, computer science, psychology, sociology, organizational theory, and anthropology (Greif, 1988). However, it is Bowers and Benford’s (1991) description of CSCW that is widely regarded as the most general definition of CSCW. They state that “In its most general form, CSCW examines the possibilities and effects of technological support for humans involved in collaborative group communication and work processes” (p. 5). In continuing this trend, the integration of web technology, collective intelligence and design are but a logical extension to this well supported area of study.

At present, the study of collective human intelligence in design is gaining traction through leveraging web-based outsourcing systems, known as crowdsourcing and blended combinations of social networks and virtual worlds to explore design collaboration (Gu, Kim & Maher, 2011; Maher et al., 2010; Paulini, 2014; Ratti & Claudel, 2015; Ham & Schnabel, 2012). Crowdsourcing

engages a web-based 'crowd' in the design process by using heavily mediated structures. Such structures require the participant to submit work according to a set of stages, which artificially models a design process. However, the online crowdsourcing structure neglects the premise that design is often characterised as much by its social activity as it is by its design activity. The process involved in extracting crowd-based intelligence in crowdsourcing denies the crowd the social opportunity to freely express design meaning independently of the mediated context (Arias, Eden & Fischer 1997; Maher, Simoff, & Gabriel, 2000). This collective approach is in direct contradiction to what Levy (1997) argued is one of the critical criteria for successful CI, which, similarly to design, is that it is a social activity where the freedom to express and communicate is paramount. Simply stated, crowd members who engage in design activity independently of one another without real-time communication during the process cannot be described as being 'collectively intelligent'. They are only collectively, but independently, participating in a task. In using crowdsourcing contexts for insight into collectively oriented design, a gap emerges in the literature regarding collective design activity in openly shared, decentralised contexts.

Taking into account key principles informing CI (the numbers of participants, their freedom to interact, their social activity and the task), contemporary methods applied in design research are not easily transferable to the study of crowd-based design activity, particularly those requiring the capture of design data from openly shared collective conditions. However, the WWW provides the necessary conditions to bring the study of crowds and their engagement with a design task within a realistic scope. For the purpose of this study it was necessary to develop a number of approaches. The initial requirement of 'how' and 'where' a web crowd were going to undertake an online design activity had to be addressed. This was achieved by adopting and adapting an easily accessible web-based platform in which all participants had complete freedom to do as they wished in regards to a design task. Once the conditions for the social interactivity have been met, CI occurs when an 'object link' is introduced (Levy, 1997). The object link is the commonly shared task, goal, problem or anything that galvanises shared activity around which the crowd can freely

engage in purposeful action. A further review of the literature in this area reveals that current methods of design research are also ill equipped for handling, coordinating and interpreting design meaning as it is carried by the representation. As such, there is a lack of tools within design regarding the capture and coding of collective design activity in openly shared, decentralised contexts. In order to navigate the exploration of design meaning, this study drew upon a number of key principles provided by C. S. Peirce's extensive writings on semiotics (1860 to 1910).

Peirce's semiotics reduces any activity, expert or not, to the same base philosophical principle; it is the combination of signs within sign systems, regardless of origin, that make up the generation and transfer of meaningful information. By providing a coordinated and systematic method to explain how meaning is constructed, regardless of medium, person, or even context, semiotics is well placed to support an investigation into the design process without specific conventions, to determine whether design meaning might arise in a collective design context. To categorise semiotic information, this study adopted Suwa & Tversky's (1997) design-related information categories to identify the areas of design-related meaning that is communicated. Given the rapidly evolving technology and programs offered through the Internet today, it is now permissible to explore design in an environment where both open social activity and design activity can be supported and captured. The emerging question is: can the crowd and CI in the Web, beyond its communicative role, meaningfully contribute to the field of design? Although still in its infancy, the growing interest in this area of research has already produced a conceptual framework (Maher, Paulini, & Murty, 2010); however, within current design research work/literature, there is a lack of understanding regarding the design-related behaviour of crowds under openly shared collective conditions and the communication and flow of design meaning within such collective contexts. This study aims to address the current lack of understanding by formulating and conducting an experiment to capture the flow of design meaning in a collective design task. This is achieved establishing a design task for an expert benchmark group and a crowd group. Both groups separately undertake a

design task in an openly shared online design environment enabling the researchers to collect empirical data regarding the role of representation in the sharing of design meaning. By developing a coding scheme suitable for handling the capture and flow of design meaning both qualitatively and quantitatively; this dissertation presents a detailed comparative analysis of the various patterns that arise in both the experts' results and crowd's results. The results will enhance our understanding of crowd-based design processes and help ascertain how humans can actively participate as the creative agent in openly shared web based collective environments.

1.1 RESEARCH AIM AND KEY CONCEPTS

1.1.1 Research aim

The aim of this research is to investigate how a crowd might conduct itself and communicate with other members in a collaborative design task.

To achieve this aim, this dissertation uses three important concepts to provide a context for understanding the aim: 1) collective intelligence in design, 2) the environmental online design conditions, and 3) the representation (discussed in Section 1.2.2). Resting upon these important concepts are two emerging hypotheses (defined in Section 1.3). These hypotheses are then tested according to four identified tasks, each of which has a series of associated research subtasks to achieve the aim (Section 1.4).

1.1.2 Definition of important concepts

Collective intelligence and design

The underlying principle of collective design (CD) is based on the central idea that it is inclusive and encourages *all* people to participate in the design process (Maher, Rosenman, Merrick, Macindoe & Marchant, 2006). To investigate this, researchers have leveraged social network systems, virtual environments and work outsourcing systems (known as crowdsourcing) to further provide theoretical insight into web-based mass participation in design. However, Maher, Paulini and Murty (2010) are quick to point out that most design oriented

systems for extracting CI from web-based crowds are based on a goal oriented system which ignores both the social and shared aspects of design. Paulini (2014) argues that collective intelligence in design is achieved through the diversity of people of “conflicting experiences, backgrounds and cultures merging into a virtually shared place”. It is this definition that is adopted, applied and explored throughout the course of this study.

The connection between CI and design is a contemporary theoretical extension of CSCW. Within the design and the CSCW a framework, CI has often been used to arbitrarily describe shared intelligence within an optimal expert group. While not strictly speaking incorrect, applying the term ‘collective intelligence’ in this context more often than not overlooks the more traditionally established conventions that identify CI as a theoretical concept in its own right; a concept that describes the shared intelligence of a *diverse* range of individuals who, when motivated, can mobilise toward achieving a commonly shared goal. Today, supported by the web and its capability to provide anybody with increasingly inventive ways of generating and sharing memetic knowledge en masse, design researchers are taking a renewed interest in CI and its relationship with design (Levy, 1997; Maher et al., 2006 respectively). One of the most significant steps forward in this area has been the development of a framework that coalesced CI with design which produced a clearer definition of *Collective Design* (CD) (Maher et al., 2006).

Online Design Environment (ODE)

The principles that govern CI, such as the criterion whereby everybody can interact—in real time—within an openly shared and decentralised system toward a shared goal, by default, establish the environmental parameters required for this study. To enable us to review how a design meaning is generated in a web context, it is important to provide these conditions. If such conditions are met, it becomes feasible for any group dynamic to interact and generate design meaning. This will allow the researchers to easily observe a) design activity and b) collect viable data. The existing tools for sharing design projects across wide domains are well documented. Tools such as Virtual

Design Studios (VDS) which are often adapted and blended combinations of various web based programs (Bradford, Nancy, Cheng & Kvan, 1994; Ham & Schnabel, 2012); and building Information Modelling (BIM) programs such as Revit and ArchiCAD. Such tools allow the interdisciplinary sharing of models and plans and BIM allows expert designers to collaborate on any given part of the shared design project. However, such programs require a high level of specialised knowledge that is not specifically available, or accessible, to non-expert designers. Although these tools do incorporate the web, allowing for a globally dispersed workforce, they are incapable of providing non-experts with simple tools or the open space in which mass participation can occur. The combined complexity and user limitations render the selection of such program suites as a highly impractical solution for the study of CI and design. For the less technically proficient, social networking websites allow for real-time communication and the sharing of images. However, these are restricted to 'live feeds' where exposure to imagery is time limited to short intervals by the constant addition of newer imagery. Moreover, the interaction with images is arbitrated and severely restricted to comments only. Specifically aimed at the non-expert designer are Mass Customisation Tools (MCTs). With fewer complexities than regular digital design tools, MCTs are offered by companies such as Nike and Ikea and are an omnidirectional, transactional tool that allows consumers to customise their product; however, this is a once only transaction and not a shared experience. Other methods for involving the non-expert in design via the web involve outsourcing of work. This outsourcing is governed by methods that mass aggregate responses and again do not provide the required open and decentralised conditions required for this study. Beyond the available approaches to mass participation and mass participation in design, it becomes apparent that there are: a) no freely open spaces where collective activity can take place; and, b) no freely open spaces specifically aimed at supporting collective design activity.

However VDS and Web-based programs which would seamlessly provide conditions specifically for CI and CD are not readily available. So to enable each participant to select their preferred medium for the purposes of generating

design meaning in relation to a set design task, it was important to find a web-based tool to adapt to an environment able to meet the required decentralised conditions and conducive to CI. To accommodate the environmental requirements which might support collective design activity (open, unrestricted, decentralised and capable of accommodating a crowd), this research required tailoring an existing web-based program, Prezi, (presented in Section 4.3) to specifically accommodate collective design activity. Its functionality was appropriated to suit our research aims and it was used as a virtually shared design space for the entire study.

Representations as carriers of meaning in the ODE

The physical interaction with various representative forms is a central factor in the process of design. The ability to visually interact with the design issue using various notational methods, or representations, provides an opportunity for designers to evaluate, discover and develop new ideas (Cross, 2006; Darke, 1979; Goldschmidt, 2004; Lawson, 1994, 2005; McKim, 1980; Schön, 1983). It is well recognised that it is this constant external interaction with various notational forms that enables designers to exchange meaningful design information quickly (Schaub & Frankenberger, 2004). To communicate design meaning effectively, designers have, over time, developed specialised conventions governing what is communicated and how it is done. The types of meaning generated are often reflected in the type of notational method employed. An example of this is the generalised flexible meaning available in the ambiguity of the quick sketch, to the more defined concrete representation of a developed design scheme (Wade, 1977). There are no specific commonly understood crowd-based conventions for design; however, Lévy (1997) states that CI arises through collaboration centred on the group's focus, which is an object link. The galvanising object link can take any form, from the initial constraints of the design problem, or 'primary generator' (Darke, 1979) or it can also be something as simple as a shared representation on a rock wall (Halpin, 2008). It is this commonly shared ability to extract and embed meaning from, and into, the representative image around which CI might coalesce with design.

1.2 HYPOTHESES

In this dissertation, the combined areas of contemporary CI principles, CI in design, web-based, environmental conditions and the representation, provide the conceptual foundation for this study. Emerging from this conceptual foundation are two overarching hypotheses which are closely related to the research aim. They are:

Hypothesis 1: The crowd will, in comparison with a benchmark of an expert group, exhibit observable differences in using the representation for communicating in the ODE in general.

Hypothesis 2: Subject to Hypothesis 1, it is expected that the experts and the crowd will have different approaches to generating and directing information for design purposes in the ODE.

1.3 RESEARCH TASKS

To test these hypotheses, the following tasks were identified, each of which had a series of associated research subtasks that needed to be conducted in order to achieve the research aim.

Task 1: To formulate and conduct an experiment to collect empirical data regarding the use of representations in collective design.

- Identify a suitable web-based context for collective design.
- Establish the appropriate experiment conditions to support an online collective design-related activity.
- Establish an appropriate experiment to compare a crowd's design-related activity against a baseline data set captured from the design activity of an expert group of designers.
- Collect and coordinate the empirical data for coding.

Task 2: Develop a coding scheme suitable for handling the capture and flow of design meaning as it is generated through the use of representations.

- Establish a theoretical foundation of a coding scheme suitable for reflecting the construction and communication of meaning within imagery.
- Establish a theoretical foundation of a coding scheme suitable for reflecting the design-related informational content.
- Establish a theoretical foundation of a coding scheme suitable for reflecting the movement of design-related meaning over time.

Task 3: Apply a general comparison using the statistical data generated by applying the developed coding scheme. This will allow for:

- A general comparison of the design activity of an expert group and a crowd during concurrently running design sessions.
- The identification and isolation of the specific similarities and differences between groups in the use of representation in the generation of design meaning.

Task 4: A detailed comparative analysis of the isolated patterns of both experts' results and crowd's results of the representation, and its role in enabling the generation of design meaning by:

- Analysing the patterns identified in the two groups to explore the differences/similarities in designers' use of representations and the crowd's use of representations in the generation of design meaning.
- Investigating the unique patterns by exploring the characteristics of representational use in open web-based contexts by both groups.

- Investigating the implications of the identified patterns for both expert designers and crowd-based design participants.

The significance of these research tasks is the additional contribution to the development of a growing body of knowledge focusing on the milieu of the web and its capacity to give rise to collective intelligence and its relationship with design. In addition, the results enhance understanding in the field of design by developing and demonstrating the application of semiotic principles in the coordination of, and analysis of, representationally oriented media in a shared web-based crowd context. The results also enhance our understanding of crowd-based design processes and help ascertain how a crowd's design capability might exist under decentralised collective conditions.

1.4 RESEARCH SCOPE AND CONSTRAINTS

Generally, there are two leading perspectives to the definition of design—both categorised according to the architectural and engineering disciplines (Goldschmidt & Porter, 2004). In engineering, the process of design is characterised as a precise, constrained purposeful exploration and learning activity (Gero, 1996); whereas architectural design is presented as a more imaginative, artistic and flowing exercise (Lawson, 2005). Both descriptions are further described as goal-oriented cognitive activities involving symbolic information processing (SIP) (Simon, 1969/1996), or alternatively, a situated reflective conversation with the design (SIT) (Schön, 1983). Underlying the activity central to both perspectives is the need to effectively generate and express meaningful information that can be easily understood and interpreted (Visser, 2007). As the focus of this thesis is representation, the engineering perspective is adopted because design activity is described as a “purposeful exploration and learning activity” (Gero, 1996, p. 435) that arises when representations are used to communicate design meaning. This transfers directly to a collective context as a general activity regarding people's capability to learn and explore, based on the use of visual media.

Before the advent of the web, it was not only beyond the scope, but reasonable logistic practicality (due to its prohibitive complexity), to use groups of people for large-scale design experiments (Yu & Nickerson, 2011). Due to the explosion of web-based technologies that enabled mass and decentralised communication alongside image-based file sharing, it is now possible to revisit more diverse conceptual definitions of mass participation in design. Using contemporary web technologies it is now possible for researchers to circumvent the earlier logistic and practical restrictions with a view to conducting larger scale and collectively oriented design experiments. It is recognised that with any digital environment there are inherent issues in how that environment might influence how design information is generated and communicated. Recognising this as a potential limitation it is important for this study to provide certain consistency in the online conditions. The selected environment aims to provide conditions which minimise - to the best of the researcher's ability – the environment interference and provide the necessary environment as set out in collective intelligence literature to support CI as it undertakes design related activity.

A particular limitation of this dissertation is centred on the use of semiotics. Many of the central issues of semiotics are still highly controversial and there is relatively little agreement amongst semioticians regarding both the scope and methodology of semiotics (Ashwin, 1984; Chandler, 2002; Corner, 1980; Derrida, 1976; Hodge & Kress, 1988; Sturrock, 1979). Semiotics is widely regarded as one mode of analysis, amongst others, rather than as an actual science. This often results in semiotics being sometimes uncritically described as a general-purpose tool that presents either overly scientific or overly subjective interpretations (Corner, 1980). Despite this, semiotics contributes a valuable conceptual framework, set of methods and terms that describe the making of meaning over a full range of signifying content. As such, semiotics in the form of the study of specific meaning making, is particularly useful to the study of design meaning when it occurs in a collective context.

Another limitation of this study was the ambiguity in defining the crowd. In order to define the web crowd for this thesis, it was identified that the top-down approach of arbitrarily defining a large number of participants was not suitable.

The approximating involved in recreating the diversity of the crowd in a laboratory environment could not be achieved genuinely by the careful selection of group members. As there is no universally agreed-upon statistical definition of a "crowd" it is important to clearly articulate how a crowd is simulated in our study. To circumvent the risks associated with claiming an 'ideal' numerical value in the widely recognised absence of such figures we adopt Surowiecki's (2004) definition of a crowd. Surowiecki states that the spirit of a crowd can be characterised according to the diversity of its constituent members (2004). This is the adopted approach for this study as there is no universally agreed statistic that defines crowd.

As the thesis required an approximation of a genuine crowd, any selective measures of recruiting members would invalidate the natural (and potentially volatile) diversity of the group mix. Instead, this research adopted a bottom-up approach by raising awareness and propagating interest aimed at directly generating a crowd of Internet-based participants. The digitally decentralised domain of the Internet presented us with the opportunity to tap into and access a portion of an immediately available 'global' crowd. Participants engaged with the experiment as a result of the awareness generated through the recruitment process which ultimately defined the numbers which constituted our crowd. Potential difficulties lay in the behaviour of the crowd as there was no indication as to what activity might occur. A natural fluctuation, and diversity within the crowd activity typically associated with activity occurring in decentralised structures, was to be expected. It was also expected that individual participants within the crowd might initially provide contributions separately to a design task in an inherently collaborative environment.

Further limitations might extend to the design brief. When providing a brief intended for both an expert and novice group it might be assumed there will exist a bias toward the expert group. In this study it is considered that the knowledge in the expert group will be present and spread throughout the crowd thus limiting any bias. A possible bias may lie in how a design problem is phrased and this is compensated for by using clear and concise language in the

brief. Because the focus of this study is on the makeup of the group and how each group express design meaning through representation, there is no emphasis on final outcomes based on the brief.

in light of the above comment. However this is a true comment and it should be recognised in the future directions section that different modes of design communication area to be explored in collective contexts

This thesis and series of experiments / data collections relied on a simulated experiment. This was not intended to be a seamless integration of collective and expert intelligence and our experiment was not intended to reflect the same mass participatory conditions as those undertaken in a real design practice. However, to conduct the study and to produce reliable data, it was necessary to control the condition of the experiments. By studying a crowd and expert designers' use of imagery in the artificially simulated web-based design experiment, it was possible to identify and begin to isolate and compare certain detailed activities and processes which inform the generation of design meaning.

1.5 THESIS STRUCTURE

This dissertation is presented in nine chapters. After this introductory chapter, Chapter 2 provides an overview of the collective intelligence and of the contemporary methods for extracting crowd intelligence in a WWW context.

Chapter 3 presents semiotics and describes how semiotic principles are applied to organise and categorise the content of the representation.

Chapter 4 presents the research methodology and research design. It begins with a detailed account of the online tool selected to host the online design experiment. This was undertaken in accordance with the first of the four identified research tasks (outlined in Section 1.4). Chapter 4 also presents the semiotic coding scheme which was developed in accordance with the second of the four identified research tasks and is also outlined in Section 1.4.

In Chapter 5, the general descriptive statistics are presented, enabling a general comparison to be applied to the statistical data. This initial comparison reveals key similarities and differences between groups. Chapter 5 is the result of Task 3 of this dissertation as outlined in Section 1.4. and contributes to the testing of Hypothesis 1 as outlined in Section 1.3.

Chapter 6 presents a quantitative comparative analysis of the semiotic and informational data. Chapter 7 presents a cumulative comparative analysis and investigates the identified characteristics of representational use in open, web-based contexts. Chapter 8 provides a quantitative comparative analysis and will test the potential movement of design information within openly collective contexts. Combined, Chapters 6, 7 and 8 are the outcome of Task 4 of this dissertation as outlined in Section 1.4 and contribute to the testing of Hypothesis 2 as outlined in Section 1.3.

Finally, Chapter 9 highlights the main findings and outlines future directions and presents further implications and the conclusion to the dissertation.

1.6 PUBLICATIONS ARISING FROM THE DISSERTATION

Phare, D., Gu, N., & Williams, A. (2013). A semiotic framework to understand how signs in a collective design task convey information, 47th International Architectural Science Association Conference, ASA, "Cutting Edge in Architectural Science", Hong Kong, China, 12-15 November 2013, pp. 473 - 482. (Part of Chapter 2 and part of Chapter 3).

Phare, D., Gu, N., Ostwald, M., & Williams, A. (2014). A method to code shifting semiotic states in design (in M. A. Schnabel [ed.]), 48th International Conference of the Architectural Science Association (ANZAScA) "ACROSS Architectural Research through to Practice", The Architectural Science Association (ASA), Genoa, Italy, 10-13 December 2014, pp. 251- 262. (Part of Chapter 4).

Phare, D., Gu, N., & Williams, A. (2014). A semiotic analysis of representational imagery used in a collective design task, *Rethinking Comprehensive Design: Speculative Counterculture*, Proceedings of the 19th International Conference on Computer-Aided Architectural Design Research in Asia (CAADRIA 2014), Kyoto, Japan, 14-16 May 2014, pp. 431–440. (Part of Chapters 6, 7 and 8).

Chapter 2: The crowd

This chapter outlines the current literature informing the study of collective intelligence in design. Firstly, some important concepts are introduced and defined. Secondly, background information about the new web-based forms of collective intelligence is provided, and how they are currently applied in design. The third section explores the characteristics of design practices with a focus on the representation as the main method by which designers communicate design intent. This forms the foundation of the coding scheme proposed for this thesis and the rationale for developing a coding scheme is provided.

2.1 COLLECTIVE INTELLIGENCE

Collective Intelligence (CI) as a concept has its roots in many contemporary and historical texts. CI appeared in, and was rigorously described sometime between the 10th and 12th century, in the writings of Al Farabi (872-950), Ibn Sina (980, 1037), Maimonides (1135-1204) and others (as cited by Lévy, 1997). CI is best expressed as a form of universally distributed intelligence, originally described as an ‘agent intellect’—a neo Platonic interpretation of Aristotle (Lévy, 1997). Originally proposed as a unique and separate phenomenon peculiar to the human race; the shared agent intellect became the prototype for the folk psychology of CI (Hogg & Vaughn, 2011). It was not until the turn of the last century that a German group named the ‘Völkerpsychologie’ (folk psychologists) prompted an etymological shift from ‘agent intellect’ to ‘collective intellect’ by contrasting Wundt’s experimental psychology of the *individual* mind with what the Völkerpsychologie termed the *collective* mind. The collective mind was established as the sociological folk study of the psychology of groups and their actions (Martin, 2007).

Inspired by dramatic behavioural episodes such as riots and revolutions, the importance of these early folk definitions was recognised. Towards the end of the 19th century, the definition of CI developed a bifurcated nature that has remained relatively unchanged to this day. On the one hand is the theoretical notion that CI can be accepted as a global intellect, whilst on the other hand the

social psychological study of large groups, or crowds, declared this global intellect was recognised in essence as being inert until activated by the behavioural need for collaboration toward a common goal (Freud, 1921; LeBon, 1896; Lévy, 1997; Noubel, 2007; Smelser, 1965). Collective behaviour occurs in almost any group situation, but is generalised as occurring within three dominant groups (Noubel, 2007): the optimal / original groups, smaller and co-located (same time, same place); the pyramidal groups, a much larger distribution of members (different time, different place); and swarm CI (biological and transactional interaction). Regardless of being original, pyramidal or swarm, the fundamental nature of CI remains the same; it is the combined efforts of many individuals pursuing the same goal, drawn together by mutual interest or a need to collaborate toward achieving a shared objective.

Original CI is the optimal group CI found in small groups which we experience every day. This is an interspecies CI that shows up among mammals such as dolphins, wolves, monkeys, elephants and so on (Bloom, 2000). All have in common the fact that they coordinate in a synchronous effort around a shared global 'object'. Apart from sports and games where players are coordinated around a material object (and likewise animals around their prey), individuals, groups and communities use daily objects or representations of objects from a symbolic and cultural space to focus their respective coordination and collaboration. There are two natural limits to this mode of CI: in number, and in space (Bloom, 2000; Lévy, 1997; Noubel, 2007). In number, only a limited number of participants can interact efficiently. Too many participants create too much complexity and generate more noise than effective results. In space, participants need to be physically together in close range so that their natural interfaces (senses) can interact. This way they can ascertain a global picture of events. Noubel (2007) refers to this shared understanding as 'holopticism', and participants can adjust their behaviour accordingly. When the number of intervening participants becomes too large, and the intervening distance becomes too great, a division generally occurs. However, other forms of CI have evolved (Bloom, 2000) to account for this, such as the organising political structures of pyramidal CI and related organisational theories.

Bypassing the limitations of optimal CI—the number of people and the distance separating them—was needed for tasks such as building, planning, cultivating and human works which required more muscular strength as well as specialisation. These activities required a larger number of participants than the optimum group would allow (Noubel, 2007). Facilitating this was the development of writing. Equipped with this capacity, representational signifiers are able to travel over long distances to a virtually unlimited number of recipients. As a result, pyramidal CI was launched which gave birth to civilisations and their states and organisational structures of governance (Lévy, 1997; Noubel, 2007). The pyramidal structure is based on the four principles of: labour division, authority, scarce currency standards, and norms. Labour division creates a division of access to information. Authority, no matter what the legitimating principle, is created by a dissymmetry in the command and control structure. Scarce currency creates allegiances and catalysed hierarchies. Finally, standards and norms are created by a language standard within a community. Language allows the interoperability of knowledge within a community (Noubel, 2007), but it is language that also forms the primary restriction of this form of CI by limiting it to localised shared cultural idioms.

In nature, a collective phenomenon has occurred naturally as a simple instinctive biological drive for survival and reproduction. It is an evolutionary design that can be witnessed in the drive of cells to organise, distribute, live and die in order to serve a greater purpose. The objective of the collective is neither sentient nor intelligent, neither is it sacrosanct or mystical. Whether acting individually or collectively, the overall result is the achievement of life and organisation whichever the form; this is the direct result of collaboration of a shared intelligence (Lévy, 1997).

2.1.1 New forms of CI

Emerging from the writings of Pierre Lévy (1994), Howard Bloom (1995), Francis Heylighen (1995), Douglas Engelbart (1992), and Francois Noubel (2007) among other theorists, the original, pyramidal and swarm CI is supported by a set of underpinning core principles. These principles outline a set of

mechanisms which need to be in place to effectively support and mobilise a functioning collective collaboration. Firstly, it is universally distributed as nobody knows everything and everyone knows something (Lévy, 1997). The decentralisation of knowledge and skills in favour of the autonomy of enhanced individuals—as creators of meaning—is key for CI to occur (McGonigal, 2008; Stremtan, 2008). Secondly, it is constantly enhanced—the continuous expansion of a space free of economic and governmental constraints and a constantly expanding knowledge space through the constant contributions of its members. Lévy (1997) articulated this as the economy of human qualities. Finally, it is coordinated in real time—constant interactivity between the individuals and their environment (technical, economic, ecological) whose modifications are perceived and controlled in real time (Stremtan, 2008). Using these mechanisms, Lévy (1997) pointed to the web as the new space which augments the theoretical cognitive consciousness through “...a tangibility provided by the joining of ideas and people in a unified manner involving communication methods based on digital information technologies”.

With computer-based communication technologies and the Internet, large numbers of people all over the planet now act autonomously. No approval is necessary from a central authority to add a page or make a link and it allows the individual full autonomy as creators of meaning. As a result we see the expansion of “inter-subjective spaces free from economic and governmental constraints” (Berners-Lee, 2010). On the web, through the constant interactivity between the individuals and their environment, modifications can be and are perceived and controlled synchronously and asynchronously (Lévy, 1997; Stremtan, 2008). Knowingly or not, participants in the web crowd exponentially develop and enhance both social media and data Uniform Resource Locator (URL) links (Albert, Jeong, & Barabasi, 1999), contributing to the continual enhancement of the web. It is now widely accepted that the web provides this tangibility and firmly underlies a new decentralised model for social organisation, based on the sharing of skills, learning and knowledge. Today, the Internet as we know it, is thoroughly integrated into our daily lives (Berners-Lee, 2010) and is creating a new space where CI can occur based on the

communication explosion of physical, symbolic and material representations (Noubel, 2007). The coordination and collaborations which arise in this cyberspace today echo Vernadsky's (1943) earlier vision of man's collective thought translated into a technological idiom.

The dynamics of CI is a complex cognitive and social issue. Originally, Pyramidal and Swarm CI were three main overarching definitions shaped by the shared characteristics of distribution, enhancement and coordination, which in turn allow for the collaboration and coordination of the group around a material, symbolic or cultural representation. The Web 2.0 adds to the traditional optimal, pyramidal and swarm paradigms of CI, a globally decentralised structure which supports both synchronous and asynchronous collaboration around a globally available set of content rich representations. In its latest stage, the Web 2.0 provides access to shared representations which are being used for a social real-time coordination of CI (Halpin, 2008). When broken down, the study of CI focuses on the collaborative and coordinated behavioural outcome of a large number of people. Beyond the theoretical cognitive knowledge space, the outcomes of CI are essentially grounded in reality through the social and psychological study of crowds and their behaviour (Hogg & Vaughn, 2011).

2.1.2 Crowd as the basis for CI

The most widely accepted definition of the word 'crowd' relies explicitly on its numeric makeup and global intent; that is, the group size and the shared goal. However there is no universally agreed-upon statistical definition of a "crowd". To avoid numerically defining such a wildly fluctuating entity such as a crowd; crowds are often summarised by their characteristics. A common definition is that a crowd is "a group event involving a large number of people in the same place at the same time acting in a collective fashion" (Martin, Carlson, & Buskist, 2007, p. 6); the adjective collective here is used to denote the diversity of its members on the whole (Surowiecki, 2004). The crowd is a vivid social phenomenon both for those who are involved and for those who witness the events first-hand or through literature and the media (Hogg & Vaughn, 2011). A crowd can also be remarkably smart and knowledgeable when their averaged

judgements are compared with the judgements of individuals (Surowiecki, 2004). Galton (1907) had already found evidence that the median estimate of judgements by any group can be more accurate than estimates of experts. The 'wisdom of crowds' effect is supported with examples from stock markets, political elections and (to a lesser degree) quiz shows (Surowiecki, 2004). It is the decentralisation and diverse autonomy within a crowd that Burns and Stalker (1961) argue provides a result far less prone to specialist professional bias, such as that studied in the 'groupthink' phenomena (Janis, 1971).

Groupthink is a theory whereby groups may make erroneous decisions when leadership and obedience (among other) factors are in play. Due to the implied scale of participant numbers and the ethical and logistic practicalities involved in field studies of the crowd, this area has, until recently, been a prohibitive undertaking. However, due to the organising capabilities of crowdsourcing and the digitally decentralised domain of the Internet crowd, we are presented with the opportunity to access an immediate global crowd where the only numeric restriction to the mobilisation of participants in any event is the awareness itself of the shared intent.

2.1.3 The unpredictable crowd

One particular drawback of the decentralised and autonomous crowd is the well-understood notion of its inherent unpredictability. LeBon (1896) characterised this as the 'madness of crowds', a theory directly influencing Waddington, Jones and Crichton's (1987) model of disorder. Just as the inherent characteristics of the crowd are able to produce accurate assessments, so too is the crowd just as likely to exhibit an inherent instability in terms of crowd predictability. Indeed one of the only predictable outcomes of the crowd is its unpredictability (Thompson, 2006). A review of historical texts, articles and documentaries reinforces this notion when looking at events such as the Tiananmen Square protest in 1989, the Los Angeles riots of 1992, Nazi rallies of the 1930s, celebrations at the fall of the Berlin Wall in 1990, and so on. As Hogg and Vaughn (2011) reflect, events involving the crowd are nothing if not varied and unpredictable, good and bad.

To a large extent, this inherently unpredictable characteristic informed the concept of a group mind, which became, in the 1890s and early 1900s, the dominant account of social behaviour. An extreme example can be found in the work of the highly critical French writer Gustav LeBon (1896). LeBon argued that crowds often behave badly because the behaviour of the individual becomes subject to the control of the group mind. Likewise, the English psychologist William McDougall (1920, as cited in Hogg & Vaughn, 2011) subscribed to the group mind explanation when he dealt with collective behaviour, devoting an entire book to the topic. Much later, Asch (1951) in his studies of groups and group conformity observed that the basic issue of antisocial behaviour in crowds should be addressed by understanding the complexities of an individual's behaviour in the context of group relations (Hogg & Vaughn, 2011). As a result, crowd behaviour in its full manifestation can be incredibly difficult to research, requiring large scale human experiments, that until recently have been both ethically questionable and logistically too complex to undertake effectively (Hogg & Vaughn, 2011; Yu & Nickerson, 2011).

2.1.4 Crowd management

Sociologically, the methods for managing large and small groups of humans has traditionally fallen (for the larger groups) to the organisational meta-hierarchy and stratification of political movements in terms of pyramidal CI. For the smaller groups, the optimal CI is the organising principle. The management of, and capitalisation upon, the smaller skill-based optimal CI (in the post-industrial professional context) is often regarded as the management of CI through traditionally hierarchical professional pathways. As Schön (1983) noted, design in particular is a good example because it is conducted within the boundaries of a stable and centralised institutional context. Design manages its associated CI through multidisciplinary design teams, represented through the interaction of professions such as architects who work alongside interior designers, planners, legal advisors and structural engineers. When the CI of a group is hierarchically organised to extract specific outcomes (that is, design outcomes from carefully selected optimal groups or design teams), this group

with a central focus and task has institutionalised and centralised professionalism.

Figure 1 highlights the implied imbalance between the professional (optimal) group and the non-professional (non-optimal) crowd, and the expected outcome versus the unpredictable outcome associated with the CI of decentralised crowds. In large and small organisations alike, catalysed CI produces outcomes from small optimal groups functioning within pyramidal hierarchical structures.

These structures are commonplace throughout many professionally specialised and commercial fields. Design professionals such as architects are built around the goal-oriented CI of specialist groups, or specialist professional designers who converge to form the optimal group (Noubel, 2007). Whether or not they are co-located, they are tasked with producing a predicted outcome based on the interpretation of intrinsic or extrinsic symbolic requirements which form the catalysing representational *object link* (Lévy, 1997).

Each specialised or professional group relies on focusing the CI through field specific representational conventions and methods of information exchange. The sharing of information is in a professional context and is governed by the representational conventions associated with that particular realm of work. For example, during the design process, professional designers use a wide array of representational methods to project and predict an expected outcome, the communication of which is governed by the use of specific linguistic (textual) or graphic (image) conventions in their exchanges. This helps greatly to limit unpredictable outcomes that may arise from the CI at work in the professional context. Moreover, it enables the designers to communicate and collaborate toward the production of an expected outcome such as the construction of a house, a high-rise building, a bridge, a monument, and so on.

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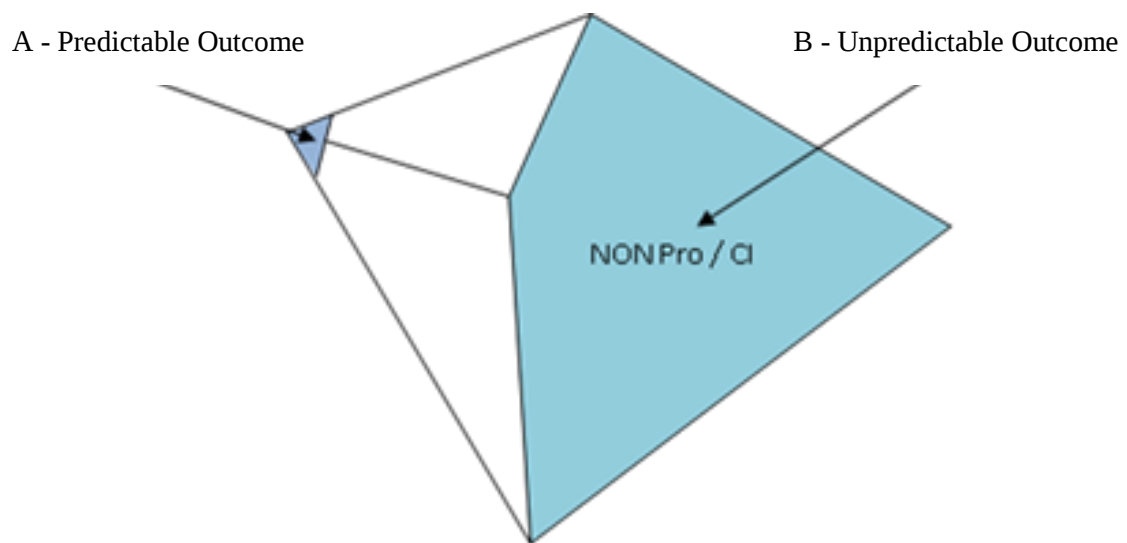


Figure 1 Expected outcomes from optimal and non-optimal groups.
(Dr Martin Cohen, personal communication, February, 2013)

¹ Diagram developed during a personal meeting with Dr Martin Cohen February 2013. The diagram was developed to quickly illustrate the proportional difference in terms of expected outcomes when non-optimal collective intelligence is compared to a small expert group.

2.1.5 Directing crowd intelligence

As shown, efforts in the management of this inherent unpredictability to produce predictable outcomes of CI typically fall, with a degree of success, within pyramidal and optimal hierarchies formulated around a centralised organisational structure. However, with new modes of CI arising from the web and its capability to provide millions of global users with the ability to exchange generalised and specialised information (both linguistically and graphically) every day in an unregulated and decentralised environment, traditionally centralised organisations are reviewing decentralised models for the organisations and technologies they construct in the world around them (Resnick, 1997). Now, not only can professionals contribute to, but can ask for contributions from, the crowd. Many novel approaches to the management of the crowd are based on task-related, shared, extrinsic or intrinsic representational methods which focus and then harness the crowd's ability to perform tasks and produce outcomes. A highly successful example of this is Amazon's Mechanical Turk, which provides 'micro tasks' to the crowd (Howe, 2009).

The seamless and boundary-blurring integration into society of the Web 2.0 and its ability to support new modes of collective intelligence has provided businesses with the opportunity to adopt new models aimed specifically at shaping outcomes from this often-unpredictable resource. At present, the pre-eminent method used to organise this unpredictability and channel it toward predictable outcomes is called 'crowdsourcing'. Through the representational use of imagery, videos, language and text, we are seeing many novel approaches to the management of the crowd's collective ability to perform tasks and produce outcomes. The crowdsourcing of Human Intelligence Tasks (HITs) is an effective method of co-ordinating and collecting human intelligence from the large number of digitally distributed participants, otherwise known as the 'web crowd'.

The following section introduces crowdsourcing and discusses the four main methods crowdsourcing uses to obtain predictable outcomes from the otherwise 'wild' CI inherent in crowds.

2.2. DESIGN INTELLIGENCE AND THE CROWD

2.2.1 Crowdsourcing

The word 'crowdsourcing' is relatively new; originally coined by *Wired* magazine journalist Jeff Howe in 2006 to describe the long standing tradition of outsourcing of HITs (Human Intelligence Tasks) to large groups of individuals. However, the concept dates back to the 18th century (Marsden, 2009). In the 1800s, early editions of The Oxford English Dictionary were crowdsourced to volunteer contributors that sent in definitions on paper slips. A century earlier in 1715, the British government ran an open contest (the Longitude Prize) to source a reliable maritime navigation solution. The prize was eventually won by a clockmaker named John Harrison, although it is interesting to note, that in Harrison's case, he was awarded the prize many years after completing the task. Upon hearing Harrison's story of how the experts' panel simply refused to believe a simple clockmaker could solve such a complex problem, the King demanded Harrison be awarded the prize money.

Today governments and industry alike have embraced outsourcing through public prize contests, and the Longitude Prize is still held. Its current challenge is standing at a £10 million prize fund to any solutions that help solve the problem of global antibiotic resistance (longitudeprize.org). NASA's habitat challenge offers \$2.25 million prize for a 3D printed sustainable space habitat (nasa.com). Similarly, private ventures such as the X-Prize contest offer \$10 million to any company or individual that can develop new methods and technologies for space flight (ansari.xprize.org). With the advent of crowdsourcing via the web, companies like XPrize and organisations like the Longitude Prize are able to reach far greater numbers of people than the British government was able to through the printed word in Harrison's day. However, despite the local versus global reach, the only differentiation is the time period.

According to Surowiecki (2004) the key principle of diversity is why these systems work so well. The diversity of the users who can be found on the web can be described as a multiplex of individuals with a myriad of cultural, cross-cultural and cross-disciplinary experiences and knowledge sets.

Although many varied sites are dedicated to crowdsourcing, the four main crowdsourcing types depend on specific underlying mechanisms which allow them to function, and can be categorised according to Howe (2006) as: 1) crowd creation; 2) crowd filtering; 3) crowd wisdom; and 4) crowd funding. Table 2.1 presents a description of how each of the four commonly accepted models functions to extract intelligence from the crowd. The four main overarching characteristics are described as:

Crowd creation: The best known forms of crowdsourcing are *creation* activities, such as asking individuals to film TV commercials, perform language translation, or solve challenging scientific problems. Creative crowdsourcing can be effective not only for sourcing new writing, photography, music and film, but for solving real-world scientific problems.

Crowd filtering: The defining characteristic of crowd filtering is that it does not directly involve or interact with the crowd. Crowd filtering is based on using third party tools and companies to assess trends in the data that is extracted from large groups. In the web, this activity is very typical and described as 'data mining²'.

Crowd wisdom: As opposed to data mining, the 'Wisdom of Crowds' principle attempts to directly harness the knowledge of many people in order to solve problems or predict future outcomes or help direct corporate strategy. Its leading characteristic is the absence of a mediator, middleman or third party.

² It is the most popular form of crowdsourcing and is often found in conjunction with other types of crowdsourcing as it capitalises on the highest levels of participation. Howe (2006) cited Yahoo's vice president Bradley Horowitz, who developed the 1:10:89 rule, which stated that out of 100 people: 1% will create something valuable, 10% will vote and rate submissions and finally 89% will consume creation.

Crowd funding: Crowd funding is an alternative method aimed at financing new businesses, ventures or charities. Crowd funding circumvents the costly traditional corporate model of venture of capitalism via presenting any type of financial opportunity for investment directly to the crowd. Crowd funding as the name suggests, is achieved via financing generated by individuals and groups who are not related to a company's internal structure (Howe, 2009).

The methods used in leveraging the differing creative, problem solving, predictive or wisdom-based heuristics from the crowd often depends on borrowing and combining the structural conventions of creation, filtering, wisdom and funding processes. As such it becomes important to recognise that, more often than not, the main principle element often incorporates elements of other types of crowdsourcing structures. The interchangeability is a considerable benefit to such web-based ventures, as the flexibility in combination allows for the method to be specifically developed to suit the particular purpose.

Surowiecki (2004), Howe (2009) and Page (2007) argue that the diversity of the crowd can perform exceptionally well when compared to the optimum group. Both Surowiecki (2004) and Howe (2009) stated that: "...given the right set of conditions the crowd will almost always outperform any number of employees—a fact that many companies are increasingly attempting to exploit" (p.16). Studies by Caltech Professor Scott E. Page (2007) reinforce Surowiecki's (2004) and Howe's (2009) claims that concentrated groups of highly intelligent people can be consistently outperformed by crowds—under the right conditions.

A notable example of the crowd's potential for problem solving when provided with the right conditions is Khatib and DiMaio's (2011) documented success of 'Foldit' (Figure 2) which was developed at the University of Washington in collaboration with biochemistry, computer science, and other departments. Foldit provided an interactive 3D puzzle game allowing any person, regardless of background, to contribute to highly complex scientific protein-based research problems. Unique to Foldit, in contrast to many other crowdsourcing websites, is

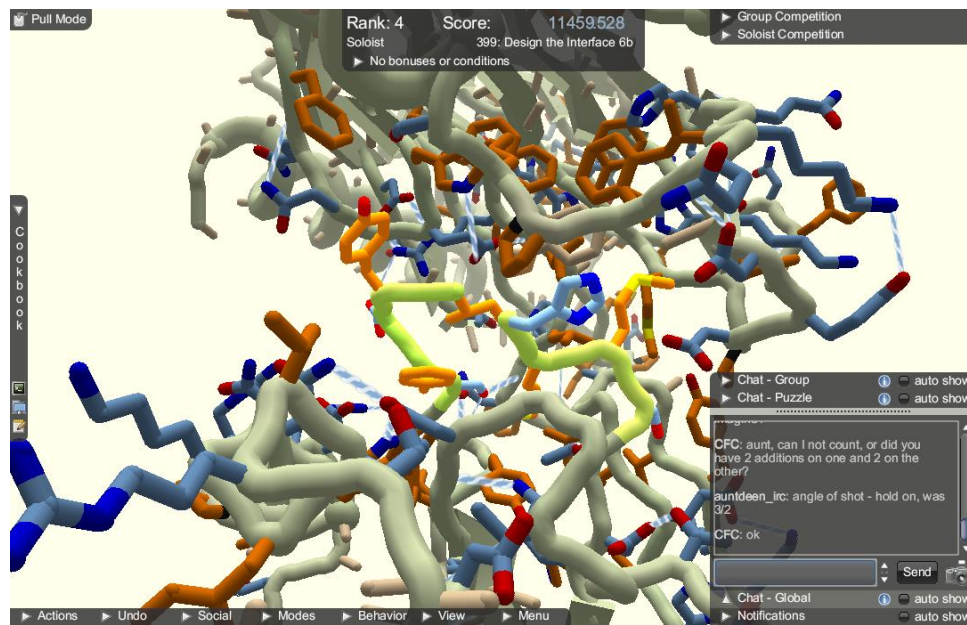


Figure 2 Foldit user interface and 3D representation of complex protein problems.

³ Image source: <http://web.cs.wpi.edu/~rich/courses/imgd4600-c15/analyses/foldit/index.html>

the method chosen to present the protein problem to the crowd. In this case, a 3D real-time representation is presented.

2.2.2 Crowdsourcing and design

Design crowdsourcing falls under the creative crowdsourcing category. Creative crowdsourcing is also providing new avenues for designers to produce work outside the traditional hierarchy of the design profession (Paulini, Murty & Maher, 2011). According to many design-related, crowdsourcing sites, the first advantage is that customers who want to acquire designs can now do so at prices they can afford. In many cases the creative crowdsourcing of design tasks is made up of voluntary participants who rely on a heavily moderated mechanism which artificially emulates a design process (Figure 3). Participants become involved in developing the design brief (Inspiration), selecting which brief progresses (Applause) and evaluating (Evaluations) the best solutions provided (Winning Concept). After review and revision, the contest then progresses and is again presented to the design crowd, often with reference images included. After a number of revision and submission cycles, the best solution wins a monetary prize.



Figure 3 OpenIDEO design process (image source www.openideo.com)

There are also open source sites such as Quirky.com, and 99designs (Paulini, Murty, & Maher, 2011)—sites which gather information from individuals and pitch those ideas to the crowd in what resembles “an ideas popularity contest” (Paulini, Murty, & Maher, 2011). They involve professionals and amateurs to varying degrees, favouring a hybrid approach where experts guide the design process and tap into the crowd’s contributions for ideas and feedback.

At present the automotive industry is leading the field in incorporating the crowd into its design cycle. Using the structures above described, the design of a car is the most highly complex artefact that the crowd has been involved in to date. A US company, *Local Motors*, used crowdsourcing structures to determine the

direction and design of a desert racer car, ultimately named by the crowd as the 'Rally Fighter'. Some 35,000 designs by 3,000 members contributed to the design of all aspects of the car. In contrast to large automotive manufacturers, Local Motors use dispersed 'micro' factories and once the design and engineering was fully developed, prospective owners participated in the construction of their new car (Wert, 2009).

When reviewing the final design result (Figure 4) it becomes clear that the design of the car is an echo of the existing Dakar (Figure 5) rally cars. The actual design outcome is an iterative combination of already existing automotive elements; a point candidly recognised by one particularly unhappy crowdsourcing group member of this product (Wert, 2009: conversation thread-same page as source). In contrast, when reviewing the concept design provided by the expert design team at Citroen (Figure 6), the final result is markedly different, both technically and visually. Consideration has been concentrated on the unique design of the tyres, as endurance rally vehicles must undergo extremes in terms of endurance, environmental obstacles and high speeds. Also extra clearance has been provided to compensate for rugged terrain, and most notably the chassis design is a single spine design that is radically different to both in production Mitsubishi and Local Motors Rally Fighter models.

4



Figure 4 The crowdsourced Rally Fighter.

5



Figure 5 The Paris-Dakar produced by Mitsubishi.

6



Figure 6 Citroën concept Dakar rally car by the in house design team.

⁴ Image source: Rally Fighter: <http://www.adandp.media/blog/post/imts-rally-fighter-in-gumball-3000>

⁵ Image source: Repsol Dakar car: <http://www.motorsport.com/dakar/photo/main-gallery/repsol-mitsubishi-ralliart-team-mitsubishi-pajero-montero-evolution-4/>

⁶ Image source: Citroën. <http://www.cars-show.org/cars/citroen-2020-dakar-rally-concept-vehicle.html>

In another large-scale crowdsourcing project, Fiat crowdsourced its design for the Mio car (Figure 7). This enterprise was mediated initially by a separate company named Agencia Click Isobar, or *Isobar* for short. Isobar is a company specifically designed to act as both firewall and intermediary between the crowd and a company's in-house design team such as the in-house Fiat Style Centre (FSC). In outsourcing the design of the Mio, *Isobar* collected 35,000 submissions on behalf of Fiat, which in turn transparently delivered the submissions to the design team at the FSC. By using the 35,000 collected opinions, the expert design team at Fiat 'cherry picked' the most popular components and these features were subsequently designed, by experts, into the Mio concept. The result of this venture was the collection of 35,000 opinions which produced a relatively extraordinary car.

Stylefactory.com is another crowd funding/design combination whereby the MyFactory section of its website offers in-house selected .jpg images and renderings of submitted designs for general viewing where members can vote to 'make it' or 'drop it' (Myers, 2010). However, what is selected is limited by the production methods used on the factory floor or limited by the opinions of other crowd members. StyleFactory's 'buy' section brings people together to fulfil those minimum orders in much the same way Local Motors used a combination of systems to generate vested interest in the design of the Rally Fighter and how Fiat used the crowd to determine the features of the Mio.

In summary, it can be argued that such environmental restrictions and current crowdsourced design mechanisms ignore the need for a specific space for the creative act to take place. At present, and under the conditions described above, the unique, inventive or radical design proposal has more chance of being overlooked through the imposed mechanisms of consensus and arbitration. This is to the point where any truly radical design submissions may simply not be proposed, generated or captured.

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Figure 7 Fiat *Mio* concept rendering by the design team at Fiat Style Centre.

⁷ Image source: Fiat Mio. <http://www.wired.co.uk/news/archive/2010-08/18/fiat-mio>

However, companies are developing ways to tap into this creativity by taking advantage of the crowd's involvement through investing in online Mass Customisation Tools (MCTs). MCTs are web-based architectures which split the role of design between users and designers and are offered by companies such as Ikea (2010) and Nike (Pourmohamadi, 2011). These tools are a near production strategy that allows the customer to tailor dimensions, colours and finishes via a web implemented Computer Aided Design (CAD) based MCT (Pine, 1993, as cited in Pourmohamadi, 2011).

The online toolkit is similar to the downgraded version of the CAD tool which designers use (Pourmohamadi, 2011). However Teresko (1994) argues that performing the user-designer role leads to confusion of customers during customisation (Pourmohamadi, 2011). Currently, the main body of research has leveraged business led MCTs as provided by such as NIKEiD and Ikea (Gero & Pourmohamadi, 2011) and sites such as Innocentive.com and BootB.com, for insight into the crowd and design.

The mediated and structured strategies for involving the crowd in the design process reveal that businesses are astutely adapting the collective 'wants' of the crowd by gauging the demand for a product and the quantity that buyers will be willing to purchase. As with any product, the key to demand is the quantity that buyers will be willing to purchase at a given price. As such, businesses which successfully incorporate crowdsourcing are able to cleverly determine the demand for a good product and to assess if the company would be able and willing to bring the product to the market at a given price. In crowdsourcing, the formal aspects of the design are carried out by a dedicated in-house professional design team (which takes place offline) and the outcomes of each stage in product development are made available online to the crowd. This is where the success of design-related crowdsourcing truly lies. In reality, it is less associated with actual acts of design and more associated with market research. The design outcomes are essentially a reflection of the in-house design team's decision-making processes based on the viable marketability of the suggestions of non-designers.

2.2.3 Conditions and Moderation

It is inescapable that crowdsourcing has become an important avenue in connecting the individual to markets and vice versa, in a mutually beneficial agreement of labour and reward provision. Through the implementation of workflows that maximise design outcomes provided by the crowd, crowdsourcing markets provide a large resource pool of shared solution-based outcomes. At present, the involvement of the crowd with design is facilitated by an archetypal crowdsourcing model. Among crowdsourcing, the most commonplace method of extracting design intelligence from the crowd is based on the widely accepted precept that the results of collective decisions—in other words, decision making guided by the aggregate of information in a social network or ‘wisdom of crowds’—reliably makes better decisions than the individual (Halpin, 2008).

Design, in the crowdsourcing context, is not living up to this expectation. Design cannot be easily described as reflecting the same practiced methods associated with the traditional professionalised discipline of design; the practice of design today is highly collaborative and design teams will often strive for a unique or innovative result. Often in crowdsourcing, the shared nature of design is sacrificed in favour of capitalising on the sheer volume of submissions, seemingly negating the need for either sharing the process of design or collaboration. Secondly, design is reflective of many processes of quick decision making centred on abstract images and sketches where there is a flow to the activity, contrary to the slow deliberate stages of the mediated crowd process (Goldschmidt 2004). Lastly, in terms of collective intelligence, there is a distinct lack of Levy’s (1997) notion of the ‘freedom’ that is required for CI to function effectively. This in turn enables Surowiecki’s (2004) key principle of diversity to successfully flourish in comparison to the optimum group.

However, Page’s (2004) widely regarded ‘diversity trumps ability’ theorem continues to influence many businesses to look to the crowd for solutions to various problems. In many areas, including Surowiecki’s (2004) examples in the *Wisdom of Crowds* and most notably Foldit.com, the results continue to add

validity to this theorem. However, the mediated systems that enable collected (Maher 2010) design, provide evidence that the very diversity which makes the crowd so powerful in other areas, is not free in many ways to directly interact and influence the design task. And it can be further argued the reason collective diversity is not trumping the ability of the optimum group in design, is because the diversity is controlled and mediated by the ability of the optimum group.

2.2.4 Research development in collective design

Brandes (2008) explored and analysed the phenomenon in which people with no formal training in design took objects that had already been designed for a particular purpose, and converted them to new uses. In western culture today, there still exists an individual capacity for design. In an ever-increasing world of pre-packaged and fabricated products, competency and professionalism in design does not overshadow the reality that a design only becomes worthwhile through its use. More often than not, things change throughout a process of use: chairs become shelves, plastic bags are used as umbrellas, lampposts are transformed into notice boards, and stairs make for excellent places to eat, hang out, and communicate. These acts of repurposing—also referred to as ‘Non-Intentional Design’—can themselves become sources for the generation of new design concepts (Busch, 2004). For example, engagement in the design process can be seen through the manipulation of everyday items. In Figure 8, bulldog paper clips are used in novel ways independently of the intention of their original design. Such examples clearly illustrate how the process of design is unregulated and unhindered by social and professional stratification.

This clearly (Non-intentional design) demonstrates a still living and vibrant capacity for design which is not restricted to professional circles. By sheer volume, this collective quotient outweighs the professional and educational professions by default. Design itself, as ability, is not restricted to the professional. Non-professionals also possess varying levels of design ability. Cross (2006) asserted that this ability is

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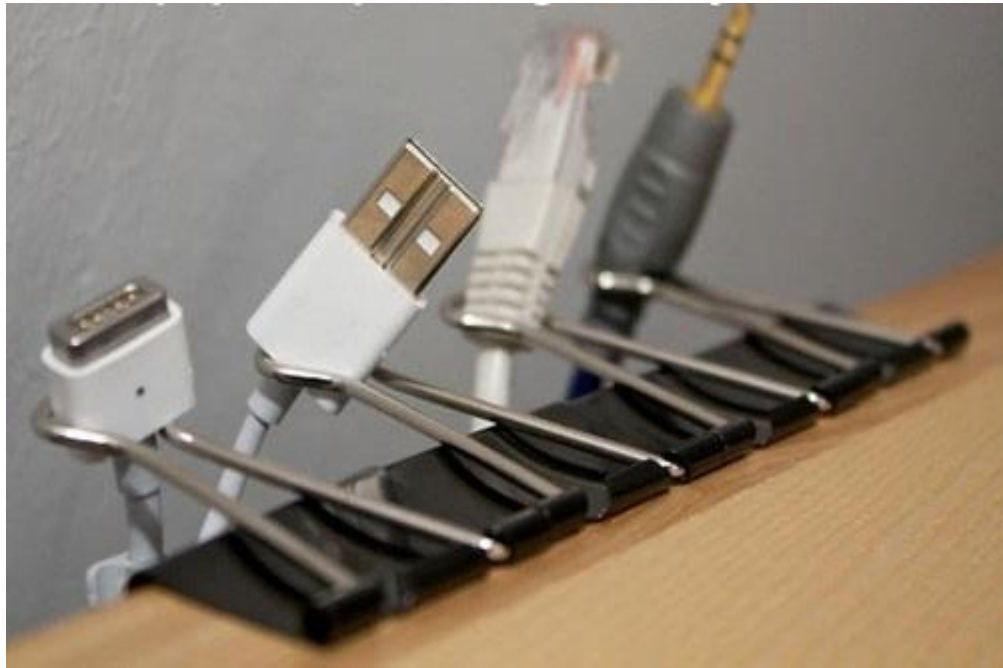


Figure 8 Typical example of non-intentional design.

⁸ Image source: <https://www.pinterest.com/pin/202873158186794660/>

collective rather than individual, and was demonstrated by the way humans continually effect change in their environment on a daily basis (Papanek, 1972).

On a more fundamental note, the use of the web to capitalise on the crowd's ability to design, taps into two other core principles: the notion of everybody as potential designers, and how people can participate more in the design process. The study of collective intelligence in design has also extended to crowd creativity by Yu and Nickerson (2011), who used Mechanical Turk combined with Google Docs as the tools to assess a 'collective creativity'. Their experiment was based on a "...variant on a human based genetic algorithm, through which the crowd participates in an iterative process of design, evaluation, and combination" (Yu & Nickerson, 2011). In Yu and Nickerson's (2011) experiment, 80 participants were initially asked to design a 'chair' using Google Docs. Then, using Mechanical Turk, 200 people were asked to evaluate the designs (Figure 9). Through a tournament style selection process, 60 designs were chosen to progress. The next stage was to ask Turk workers to combine elements of the existing selected chairs with new elements. The next four sequential combinations progressed using the same method until 1,047 participants were involved in the experiment to develop a number of chairs selected by the crowd.

Leveraging CSCW in design background, a few researchers have begun to review the potential role that a crowd might play in design. Some of the earliest contributing researchers are Maher, Paulini and Murty (2010). They have proposed a conceptual space for 'Collective Design' based on the overall key areas of Communication, Motivation and Representation (Figure 10).

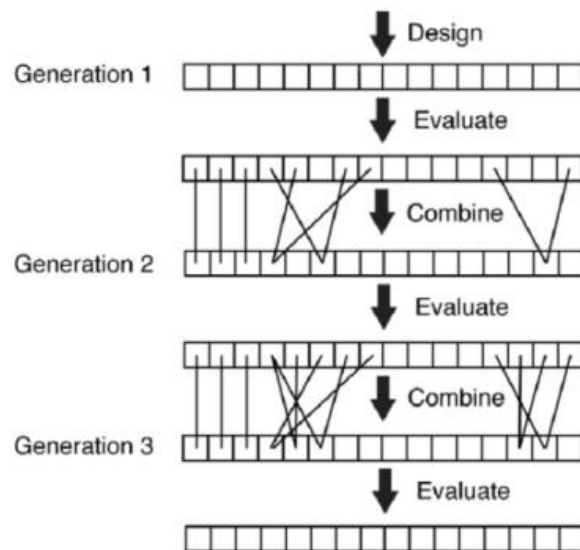


Figure 9 Yu and Nickerson's' approach to exploring crowd creativity (2011).

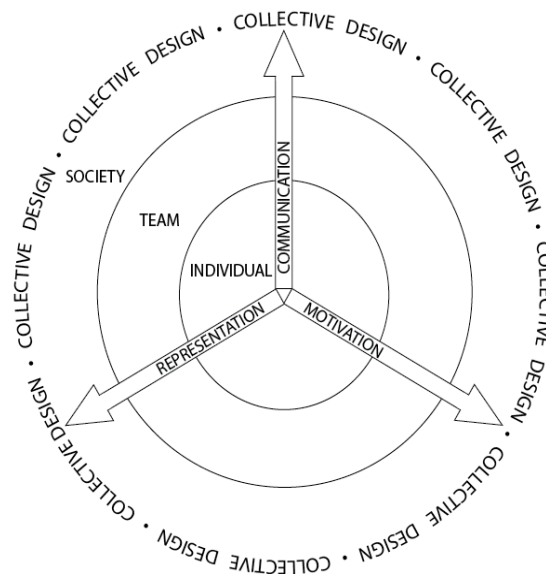


Figure 10 Conceptual framework for Collective Design by Maher, et al. (2010).

Representation refers to the digital models and files that support visualisation, analysis, and synthesis. The representation can be text, sketches, 2D models, 3D models, and any media that supports communication of design information. Communication refers to the ways in which people can communicate during the design process, for example via blogs and email, and can be characterised as synchronous or asynchronous, and as direct or indirect. Motivation refers to the principles of motivation and the way the underlying reasons for participation in the design process are undertaken.

It is widely understood throughout the literature that utilising and manipulating representation plays a key role in exploring and communicating complex design problems and their solutions. Likewise many types of representation are needed to support effective enactment of ‘collective’—occurring collaboratively or otherwise—and not ‘collected’ intelligence (Halpin, 2008). At present there are few to no other representative forms at play in the crowdsourcing context.

Acknowledging that the text plays a pivotal role as the generator in catalysing a large number of collected design responses; crowdsourcing design websites offer little to no solutions for the motivated design participant to engage in the ‘collective’—collaboratively or not—shared design process. Whilst capitalising on collected design intelligence may prove useful in the search for contributions to a solution space, there may be much more innovative potential within the diversity of crowd than is currently being experienced. Many potentially innovative ideas are likely to fall by the wayside through the lack of being able to explore the design issue in an openly shared problem space which enables multiple, and directly modifiable, shared, representational contributions to the design problem exploration space. Yu and Nickerson (2011) recommend in the conclusion of their study that:

...the system might extend its use of collaborative mechanisms: The coordination between participants provided in the current system is minimal. That is, no participant interacts directly with another. Instead, only some participants see the previous work of two others: all co-ordination is mediated through the designs (p. 1400).

The decentralised independence of crowd-based participants makes possible large-scale parallel efforts, but Yu and Nickerson (2011) followed their recommendation with a suggestion that more interaction might be useful for deeper idea integration. At present, sequential combination is the preferred model to produce crowd-oriented design, both in the laboratory when studying motivational, communication and creative aspects, and through commercial crowdsourcing.

A review of the literature reveals that many types of representational objects are needed to effectively enable the enactment of collective intelligence whether it occurs collaboratively or otherwise (Halpin, 2008; Levy, 1997). By accepting the importance of the role of representation for both expert design and collective intelligence, it can be determined that, apart from the expert designers, there are little to no shared representative forms at play in the design crowdsourcing context. Due to the infancy of the field's relationship with the crowd beyond localised studies of participatory design, a literature review reveals that the relationship between shared design representation, design collective intelligence and the crowd has, to date, been minimally explored.

2.3 SUMMARY

From the review of CI and the crowdsourcing literature presented above we are able to understand how crowds are used commercially for design purposes. The current method of extracting design intelligence from the crowd, while effective in terms of multiple design outcomes, has no support for shared design processes. Crowdsourcing sites neglect two key elements that: highly capable people are completing these tasks and they are completing them alone. The people who complete these tasks not only follow directions to complete a task but also think creatively, socially interact and make complicated judgements. They are not "...solely input / output functions that take HIT and produce a unitary product that is either approved or denied for a given payment" (Rzeszotarski, 2011, p. 1). Human beings are well adapted toward working in groups and organising labour; a fundamental requisite for CI to occur. Through analysing the conventions used by crowdsourcing markets, there is a clear

indication that once workers in the crowd have received a description of the design problem or task, they are almost certain to be forced to work away from the crowdsourcing environment, without ever having collaborated. To leverage a pathway into the study of collectivity in design, current research has so far utilised information gathered from established crowdsourcing websites. The drawback of this approach seems to be that there is no actual design activity, in the traditional sense, taking place at all.

However, current research has provided an invaluable theoretical framework for CD consisting of three principle areas: Communication, Motivation and Representation. Much of the existing literature to date has observed communication and motivational aspects of the participants yet there is little research in the area of representations in CD. However, both Maher and Paulini's (2010) account of CD and Yu and Nickerson's (2011) review of collectivity in design, recognise the absence of collaborative software that can provide many participants with the ability to communicate and collaborate on design issues.

In highlighting these points, the above literature review reveals significant gaps. In terms of collective design activity, crowdsourcing is essentially without any support for the sharing or interaction between motivated crowd members. Moreover, it is recognised throughout design literature that design outcomes rely significantly on the interaction with representations. However, due to the lack of support for shared, web-based design activity, there is no collectively shared space for the necessarily important interaction with the representation. To address these gaps, this research study uses a suitable web-based application for adaptation in order to study a crowd. as it uses representations to engage in a design task. The web application will support a large number of concurrent members who can freely interact with each other. Furthermore, the web application will support multiple types of visual media. Taking this approach will allow for a) the study of a space for online design activity, b) observation of the crowds in a web-based design experiment and, c) observation of how representations are used in web-based crowd design activity.

Chapter 3 provides the second part of the literature review and discusses the design representation as being the central vehicle for the communication of meaning. A synthesis of both literature reviews follows, in which an overall conceptualisation is provided.

Chapter 3: Representation

Supporting much of this work is the study of professional designers in the engineering and architectural design fields; both understood as rich research resources due to their long-standing specialised status. Design research that concentrates on these groups is often concerned with small tasks focused on the observations of designers designing or the coding of this activity.

Regardless, they are examined in artificially restricted laboratory conditions, where potentially only several critical, distinctive characteristics of design only appear in professional design (Visser, 2007). It is under these conditions that many studies have shown that the exploration of the *design problem space* is undertaken through interacting with representations in order to communicate solutions and ideas (Newell & Simon, 1972).

3.1 DESIGN REPRESENTATIONS

It is difficult to understate the relevance of the representation in design. Not only is it the leading symbolic method of communicating design descriptions to a greater audience but it also facilitates a complex personal cognitive interaction in the design issue (Schön, 1983).

3.1.1 Type and Content

The use of representational media in design is often diverse, limited only by its stylistic application. It can be described as an analogue system (tracing paper, graphite and ink) or a digital system (involving virtual reality, scanning, 3D CAD modelling, animations and rendering) (Bermudez & King, 2000). In professional design hierarchies, these are described as the medium which carries the information, making both analogue and digital formats a *Type* of representation (Goldschmidt, 2004; Maher, 2010). The second category is *Content*. Content is the shared description of parts relating to, or of, the design problem (Goldschmidt, 2004; Maher, 2010). It is the fundamental representational elements of Type and Content which, when combined, are used to effectively describe and communicate design information.

To organise this diverse and potentially limitless array of Type and Content, designers tend to co-ordinate the method by which it represents information into a coherent system (Wade, 1977). This co-ordinated use of representations informs a standard vocabulary of notational use which helps the professional select the best media for the relevant stage of the design process. The type of representational media changes at each stage of the process, to enable a more precise representation of the evolving design itself (Wade, 1977). Often Type and Content are organised according to a distinct set of design related phases (Verstijin & Goldschmidt, 1998) in order to manage the design process in its entirety. They are the conceptual, the schematic, the developed and the final phases. The media-conveying design content is a situation-dependent condition with designers choosing the appropriate means of representation that are specific for every phase of the design task (Goldschmidt, 2004).

3.1.2 Process

In addition to the external communication of design information, the representation is the tool by which designers record certain cognitive procedures when deciphering design problems (Dave, 2000; Simon, 1973). In Eastman's (1969) words "the representation of design problems holds the key to their solution". Visser (2001) expands upon the relevance of using representation within this process by stating that design is:

...the construction of representations. This characterises the underlying activity as being multifaceted: its ill-definedness, complexity, ambiguity, the incomplete and especially the conflicting nature of its constraints—and the importance of representations, diverse with respect to their abstraction and precision, their internal or external, notational or non-notational character. (p. 32).

From the last three decades of research in design, an understanding has emerged of the complex cognitive relationship existing between the designers in terms of reasoning processes taking place whilst using representational media (Cross, 2001; Dillon, 2010; Rittel, 1987; Schön, 1983; Visser, 2007). Emerging

from this is a focus on the area of reasoning processes within design, the relevance of which was succinctly described by Rittel (1987) in which he states that “only at the microlevel can we identify patterns of reasoning corresponding to [the design process]” and understand design activity (p. 3). As such, reasoning as studied in design, is presented through selected models of problem solving and design activity (Cramer-Peterson, 2015; Simon, 1973). Studies in design reveal consistently that in order to understand design it is important to leverage the content of their interactions with various types of imagery (Goldschmidt, 2004; Schön, 1983; Suwa & Taversky, 1997). The use of internal (in the designer’s mind) and external representations, as well as switching between both types of representation, are essential mechanisms of thinking and acting in design (Dorner, 1998; Hacker, Sachse & Schroder, 1998). This strategic arrangement of graphics, symbols, and characters with abbreviated expressions, when combined, form a communication convention which enables designers to describe with limited confusion:

...everyday objects in space through [the use of] drawings, sketches, physical and electronic models. The power of analogue representations is based on the directness of their correspondence to reality, the accuracy with which they simulate objects and the evaluation of important design performance issues they enable, such as composition, contextual congruency, and constructability (Akin, 1987, p.3).

Communication of these explorations and possible solutions in design is based on the structuring of various notations made possible by specific collections of commonly shared and understood signs; each sign chosen for its ability to express particular meaning in a coherent and structured manner. In summary, the purpose of design notation is to record information about something that does not yet exist in such a manner that the designer, and others, can manipulate that information to find possible solutions (Ashwin, 1984). Just as design activity depends on specific signs captured within a representation, so too does the representation carry signs for the purpose of expressing meaningful content outside of design. Whether a designer has designed a sign

or not, what makes something a sign is human intention; an entity becomes a sign only as the result of a person using it to denote or refer to something (DeLoache, 1995). It is the interaction with signs and symbolic content that is a quintessentially human capability when it comes to design because the signs and symbols are denoting things that only exist as an idea, and do not exist in real world yet. The implications of this lend themselves well to the notion of the use of signs in a collective design context when it is thought that the representation will play a pivotal role in the generation of that meaning. Informing the study of signs is the philosophy of philosopher C.S Peirce and linguist Ferdinand de Saussure's work on semiotics, which is introduced and discussed in the following section.

3.2 REPRESENTATIONS AND MEANING: SEMIOTICS.

The most direct definition of semiotics is that it is the study of signs. To expand further, Eco (1976) states that semiotics is "concerned with everything that can be taken as a sign". This involves "not only what we refer to as signs in everyday speech, but of anything which stands for something else" Chandler (2002). Early semiotics focused primarily on language and the 'sign'; however, in modern semiotics 'signs' include signs as images, words, gestures and objects (Chandler, 2002) and are not studied in isolation, but as part of 'sign systems' which investigate how meanings are made and how reality is represented through varying forms of text and media.

At the turn of the century, and working independently of one another, the Swiss-French linguist Ferdinand De Saussure (1857-1913), and the American philosopher Charles Sanders Peirce⁹ (1839-1914), are credited with establishing the two major, and mutually interchangeable, theoretical traditions in the study of signs and their meaning. In differentiation, the 'Sausserian'

⁹ All references for the work of C.S Peirce come from the collected works published by: Peirce, Charles Sanders (1931-58): *Collected Writings* (8 Vols.). (Ed. Charles Hartshorne, Paul Weiss & Arthur W Burks). Cambridge, MA: Harvard University Press. Any direct reference of the collected papers is written as: CP (collected papers), Vol number (1 through to 8). This is followed lastly by the entry number (E.g. CP 3:340).

tradition is sometimes referred to as 'Semiology' whilst the 'Peircean' tradition is sometimes referred to as 'Semiotics'. The terms 'semiology' and 'semiotics' are more or less synonymous, the former being derived from the French *semiologie* and the latter from the English variant (Ashwin, 1990). However, today 'Semiotics' is the umbrella term most widely used to embrace the whole field (Noth, qtd. in Daniels, 2002)

For Saussure 'Semiology' was a model for understanding the role of signs and their meaning as part of social life. His study of signs titled "Course in general linguistics" (posthumously published 1916) pertained to their function within the framework of his linguistic studies of the early 1900s. Saussure maintained that both the visual image and the word were psychological imprints that became connected in language (Chapman, 2004). Using his linguistic model to search for deep structures underlying the surface features of phenomena such as simple naming conventions (Chandler, 2002), he argued that human culture may be understood by means of an embedded connection in the structure of language (Chapman, 2004) This approach facilitated the later genesis of the philosophical and intellectual landscape referred to as Structuralism. Saussure's linguistic model comprises a dual nature whereby the sign was very different to being merely a name bearing a psychological connection to the concept that was central to the earliest foundations of language.

The sign, according to Saussure, can be broken down into two primary components: "the signified (concept) and the signifier (sound-image)" (Figure 11) (Chapman, 2004), both of which were purely psychological in construct. The function of the sign is to "...communicate a message, and in a purposive communication, the process requires two participants, an emitter and a receiver. The message is embedded in a medium (object) and subsists in a set of conventions or codes" (Ashwin, 1990, p. 43). These two components, according to Saussure, are the fundamental characteristics of any linguistic sign.

While the French-based Saussure was pioneering the study of semiology, in America, Peirce was developing his theory of semiotics, also defined as the

study of signs and signification (Chapman, 2004). However, for Pierce, semiotics was a formal doctrine of signs more closely related to logic (Chandler, 2002). The important differentiation between the Saussurian semiology and Peircean semiotic theories is that “the ‘sign’ has an added dimension in Peirce's semiotics: the duality of Saussure's model has become a triad” (Chapman, 2004 p.387). In Peirce's semiotics the sign has become the representation of an idea to a receiving interpretant. There is no longer a direct relationship between the concept and ‘soundimage’. It is now conditioned by the third component—the interpretant, which is the individual receiving and processing the information (Chapman, 2004). This relationship is illustrated in Figure 12.

In Peirce's semiotics the interpretant introduces perspective to the logic of signs absent from Saussure's model; it implies an act of individual interpretation (Chapman, 2004). For Pierce the sign is encoded by the emitter in a medium (Sign-object): this medium is then taken and decoded by the receiver or interpretant. As a result, the representamen in Peirce's theory does not carry universal meaning, but is related to the individual who interprets this representation, with infinite possibilities of interpretation. Pierce's contribution of the interpretant plays a major role in allowing contemporary semioticians to narrow their focus to how meanings are interpreted with signs, not just with how languages operate in their communicative function (Chandler, 2002).

Both Saussure's and Peirce's theories were relatively obscure during their lifetime, with the works of both being published posthumously (Chandler, 2002; Chapman, 2004; Lawler, 2004). Based on Saussure's work in structural linguistics a resurgence in semiotic theory occurred after the Second World War, fuelling the intellectual stream of structuralism. It is difficult to disentangle the development of European semiotics from structuralism in its origins; major structuralist's include not only Saussure but also Claude Lévi-Strauss (b. 1908)



Figure 11 Saussure's model of the sign (Chandler 2002).

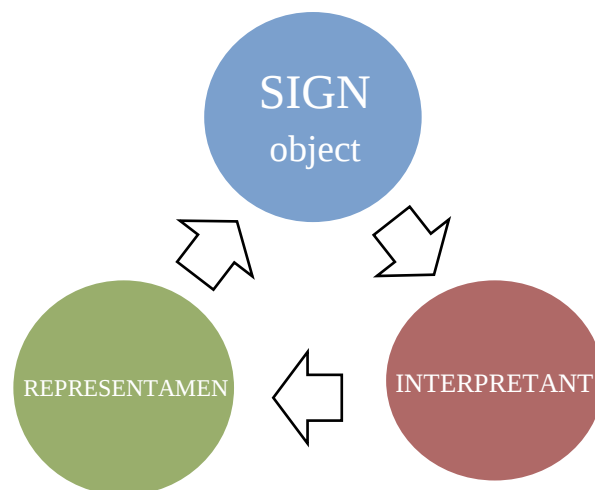


Figure 12 Charles Sanders Peirce - the semiotic triad (Chandler 2002).

in anthropology (who saw his subject as a branch of semiotics), Jacques Lacan (1901-1981) in psychoanalysis, and Wilhelm Wundt (1832–1920) in psychology, whose work (later described by Titchener) was an analysis of the basic elements that constitute the mind. Structuralism is an analytical method which has been employed by many semioticians. Structuralists seek to describe the overall organization of sign systems as languages—as with Lévi-Strauss and myth, kinship rules and totemism, and Lacan with the unconscious (Chandler 2002).

The chief protagonist in revisiting Saussure's and Pierce's work after the Second World War was the anthropologist Roland Barthes in the 1960s in his popular essays entitled *Mythologies* (Barthes, 1957). Whereas Saussure and Pierce focused on linguistics, it was Barthes who believed semiotics could be applied to imagery. He used semiotics to explore the use of signs in the image medium to demystify and expose—allied with a politically Marxist perspective—the contradictions that he perceived in the then contemporary French bourgeois social climate (Chandler, 2002). Barthes's approach to semiotics was to stress the role of ideology in the image (Chandler, 2002). Where the Saussurian and Peircean semiotics structuralist landscape focused primarily on linguistics, Barthes's anthropological approach used the social context to shift the focus away from the linguistic sign to focus on the way people use the medium, such as images as semiotic resources, both to produce communicative artefacts and events, and to interpret them in the context of specific social situations and practices (Van-Leeuwen, 2005).

From Saussure's, Peirce's and Barthes's lead, linguistic and visual signs are now traditionally classified into three groups; the index, icon and symbol, each with numerous possible subdivisions. The index is a sign that arises as a result of the object that it signifies. An index indicates something: for example, 'a sundial or clock indicates the time of day' (C P 2:285). Other examples are the footprint as a sign of an earlier presence at a given spot or smoke as a sign of fire. The icon (from the Greek word for image) is a sign that bears a similarity or resemblance to the thing it signifies. Road signs presenting a schematic image

of, for example, animals or vehicles fall into this category, as do more elaborate depictive drawings and paintings. Finally, the symbol is a sign which bears no apparent resemblance to its related signifier, but operates within an agreed set of conventions. For example, the word 'tree' has no obvious similarity to the object it denotes, and totally different signifiers are perfectly adequate in other languages (arbre, baum, albero). Other typical examples of symbolic systems are the Morse code and flags. Because they manifest a deliberate desire for resemblance or similarity, icons are sometimes described as motivated signs, whereas symbols are regarded as arbitrary or conventional.

Barthes's Semiology aimed to take in any system of signs, whatever their substance and limits; images, gestures, musical sounds, objects, and the complex associations of all of these, which form the content of ritual, convention or public entertainment: these constitute, if not languages, at least systems of signification. This provided the basis for the later notion to social semioticians that there can be no exhaustive semiotic analysis because every analysis would be located within its own interpretation arising from a particular social sphere and historical and cultural context.

Despite the wide range in application, semiotics is not often considered a specific academic discipline in itself. Semiotics continues to be applied through many varying theoretical stances and methodological tools across many areas of research—however philosophically influenced. The paradigms of Saussure, Pierce and Barthes remain a dominant influence on semiotic philosophy today. As our cultures undergo drastic transformations through conditions afforded by web-based mass communication in the 20th century, the role of semiotics may yet find a more focused academic role of its own. As such, semiotics still informs, but not at its core, the investigation and application into many academic disciplines such as media studies, art, music, theatre, psychology, film, advertising and design.

3.3 SEMIOTICS AND DESIGN - A METHODOLOGICAL BACKGROUND

To date there is little in the way of a comprehensive history in regards to the development of semiotics in architecture. The most recognised and nearest available equivalent to a history of the development of semiotics in architecture is Paul Walker's unpublished dissertation; *Semiotics and the Discourse of Architecture* (Walker, qtd by Diaz, 2008). In his dissertation he recognises that many of the semiotic theories within the field of architecture commonly lack agreement and that individually, the current theories impede rather than foster theorizing with respect to semiotics and architectural design discourse generally (Walker, 1986). At present semiotic theories of the built environment reflect a typical criticism aimed at semiotics in general, which is that semiotics is often subjectively applied as a general tool, often applied to an area of study without any specific limitations (Chandler, 2002).

In search of a theory for a field of human practice typically characterised by a lack of conceptual discipline, early design professionals, especially those formed in the Ulm school tradition, were willing to adopt semiotics as their theory (Nadin, 1990). The Argentinian painter Tomas Maldonado (1967) was receptive to structuralism in semiotics and made it part of his own mathematical design concept. Fundamental to Maldonado's semiotics was a reference relationship where texts, graphics, photography became natural candidates for semiotic analysis. From Maldonado's published work 'Is Architecture a Text?' we can possibly trace some of the first connections between the Ulm school, semiotics and architecture.

It was George Baird's "La Dimension Amoureuse in Architecture" (1967) which formalised the theoretical connection between the work of Saussure and architecture (Chapman, 2004). However, it was Charles Jencks who was actively involved in popularisation of this appropriation. Jencks's essay titled *Semiology and Architecture* (1969) provides the most enduring model of semiotic analysis in architecture (Chapman, 2004). Likewise, in their later articles *Function and sign: Semiotics of Architecture*, Umberto Eco (1969) applies his semiotic theory to architecture, and Preziosi's *Architecture*,

Language and Meaning (1979) again applies a rigorous account of semiotics in architecture.

One commonly shared theme emerging from the works of Baird (1967), Jencks (1969), Eco (1976) and Preziosi (1979) is the epistemologically analogous relationship between architecture and semiotics that resides at a 1:1 scale. This relationship has remained largely unchanged and is based on the meaning embedded in a hierarchy of codes such as building, language and drawing related signs (Walker, 1986). It could be argued that Jencks (1969), Baird's (1967), Eco's (1976; 1997) and Preziosi's (1979) discourses exhibit the hallmark criticisms of semiotic analysis (imperialistic, methodological and subjective). Their semiotic theories have endured, and to date, they largely remain representative of the relationship between semiotics and the built environment.

Whereas the semiotics of Saussure and Peirce are representative of the structuralist approach, they are characterised as a systematic search for underlying structures to the surface features of phenomena (such as language, society, thought and behaviour) (Chandler, 2002). Contemporary social semiotics has moved toward the poststructuralist analysis of meaning making by rejecting the notion that meaning is assumed and is there to be interpreted; instead, in contemporary semiotics, meaning is generated internally via a complex relation of parts within a self-contained personal system, influenced by pre-existing things (Barthes, 1967; Derrida, 1976). Indeed it can be argued that, for a successful synthesis of new information, designers are taught to engage internally with the outside world in order construct new meaning based on existing information.

Leveraging the relatively recent field of visual semiotics scholars, such as Nadin (1990) for example, who authored an investigation of the role of semiotics in design activity, though mostly with a focus on developing a model of semiotics for design rather than applying semiotic principles to investigate design activity. More recently the Peircean semiotic model has been directly applied to social tagging in web-based communication (Huang & Chuang, 2009), and Arnellos,

Spyrou and Darzantez (2007) authored a paper on developing a computational model of semiotics for creativity. Nadin (1990) argues that “Design principles are semiotic by nature” (p. 269). He explains further:

To design means to structure systems of signs in such a way as to make possible the achievement of human goals: communication (as a form of social interaction), engineering (as a form of applied technical rationality), business (as a form of shared efficiency), architecture (philosophy, manifesto, and space syntax), art, education, etc. (p. 269).

Undertaking this mutually dependant and twofold activity, architects and other designers seamlessly play out a complex cognitive–physical–cognitive–physical working relationship with representational media in order to depict everyday objects in space. This is achieved through drawings, sketches, physical and electronic models and more often than not, the use of analogue representations because of their directness of correspondence to reality (Akin, 2001). If we review Pierce’s three-fold trichotomy when applied to representations that are employed in a design context, the importance of the concept of iconicity is immediately obvious. Much representation in relation to design is dedicated to the recording and transmission of resemblances (Ashwin, 1990). The process is enabled by the attempt at representation, the external recording of a phenomenon already present to the senses, or presentation, the process of making material an otherwise immaterial form or idea that existed only as an idea or concept in the designer’s mind until its commitment to paper or as an idea expressed through image types.

Hall (1997) building on Pierce’s trichotomy and clarifying Barthes’s argument that semiotics applies to any, if not all forms of imagery as well as linguistics, argues that there are two systems within representation. He states, “First, there is the ‘system’ by which all sorts of objects, people and events are correlated with a set of concepts” this is in correlation with mental representations that we “....carry around in our heads” (p. 3). This system is comprised of our own personal interpretation of the complex relationships that allow us to mentally associate one thing with another. The second system is language. The language

system allows us to share and communicate the meanings and concepts we hold mentally (Hall, 1997). It is within this second system of language that signs (icons, indexes, and symbols) function. In contemporary, post structural semiotics, meaning in language is not limited to the use of the spoken and written word; it considers the visual image as an equally vital component in the making of meaning. For a representation dependent field such as design, this relatively new semiotic appreciation for the visual is slowly reigniting interest and debate in the design field.

3.4 SEMIOTIC QUALITIES AND SHARED PICTORIAL COMPETENCE

The literature review above is drawn from existing works; however, this section serves to provide an original synthesis in respect to design, collective design and the representation. By viewing design through the semiotic lens we are able to apply the relationship between the signified, signifier, interpreter, symbol, icon and index as potential mechanisms that may provide window of opportunity for a commonly understood, shared, sign-based, collective design language, a language which can be used—cognitively—by a web-based crowd to express ideas, design intentions, directions and aims based on the use of images whilst not explicitly relying on collaboration.

The particular notational medium for conveying symbolic content is a situation-dependent condition in which designers choose the appropriate mediums of representation that are generally understood within the context of the profession using it. Practices such as engineering design, architectural design, interior design and graphic design have developed their own visual linguistic hybrid sign systems for communicating aspects of the design scenario and is different at each stage of the design process. On the nature of signs and symbols as discursive elements in the design process, Ashwin (1984) elaborates on the hybrid structures employed by different types of designer:

Although they normally make extensive use of iconic systems based on resemblance, employing such techniques as representational scale, perspective, tone, and texture, they often introduce purely conventional

symbolic systems such as codes for the representation of cross sections, interruptions of form, or the depiction of materials, colours, and textures in black and white. This point can be argued further: that even the most unproblematic drawing from observation may contain conventional signs not explicable in terms of resemblance, such as a linear profile representing the boundary of a plastic form in space (p. 44).

In the wake of Simons's (1969) view that design is a cognitive activity of which everybody is capable, followed by Christopher Alexander's 'pattern language' (1977) book which provides all essential patterns for successful architectural design. Since then a growing number of researchers have focused on the potential of the user, or non-expert designer. For example, Cross (2006) asserted that the ability to design is collective rather than individual. Busch (2004) further demonstrated the way humans continually effect change in their environment on a daily basis, by describing 'non-intentional design' as the source for the generation of new design concepts. Under review, it becomes apparent that there is a slowly growing body of design literature that is emphasising the potential of the non-expert for design. Practical examples of this can be observed by early attempts of Nike Shoe Company to harness this capability by offering each customer the ability to customise their own shoes (Pourmohamadi, 2011).

A leading distinction between the expert and the non-expert designer is the marginalisation of the non-expert through the pictorial conventions established for the structured communication between expert designers. Designers are highly trained and exploit the informational potential of various notational objects to effectively communicate design descriptive signs. Despite the non-expert not possessing this skill, the ability to exploit the informational potential of various notational signs, including models, maps, and pictures is universally a human skill. It is mastered at a young age and it allows us as human beings to participate fully in society (DeLoache, 2003). This sign-based ability, described as pictorial competence, allows us to perceive, interpret, understand, "...and use pictures, ranging from the straightforward perception and recognition of

simple pictures to the most sophisticated understanding of specialised conventions such as those of designers” (DeLoache, 2003). Pictorial competence describes our ability to perceive and interpret the signs in any given picture; it is the act of not only seeing the representation—the picture surface—but also “sees through” it (DeLoache, 2003, p. 115) to its referent. This collectively learnt and universally shared competency places us in a strong position to revisit Ashwin’s (1984) ideas of how connotative and denotative signs embedded in representations can be interpreted when applied to design in truly collective contexts.

The expert designer’s use of representations is governed by a discipline-specific set of conventions allowing for the structured communication of design-related information. For the crowd, shared information and imagery enables the effective mobilisation of collective intelligence. The members of design teams and the individuals within a collective context share a commonality in that they both rely on communicating and interpreting connotative and denotative sign-based meaning via the representation. This is achieved by drawing on a commonly shared human trait; pictorial competence with linguistic and visual notation systems. When combined, the interdependent nature of notational languages are concurrently sign based, graphically constructed and globally dependent on a shared pictorial competency; all of which are well accounted for by the semiotic principles in the classification of iconic, indexical and symbolic imagery. As such, semiotics is well suited for an investigation into how a potentially infinite number of meaningful signs can be generated, combined and interpreted by anybody, in an openly collective design context.

3.5 SUMMARY

In summary, the representation has long been recognised as an important vehicle for generating and communicating design meaning (Goldschmidt, 1991, 1994, 2003; Schön, 1983; Asimov, 1962; Suwa & Taversky, 1997). Despite the emergence and increasing adoption of web-based and social media environments in design there is a lack of an effective method for capturing and understanding the use, and the information flow, of these media-rich

representations in these environments. Moreover, many approaches to traditional design studies also do not handle the capture of design-related meaning. On the contrary, semiotics provides a coordinated method for understanding how meaning is constructed and communicated via its sign-related qualities. In reviewing design-related activity in terms of signs and meaning, semiotics becomes a useful tool for studying how images are used to generate meaningful content, regardless of their origin, number or context. In order to study the flow of meaning in a design context it was necessary to address the current lack of available tools which would allow for such an undertaking. In isolation, semiotics relies on qualitative interpretation and alone is insufficient for a detailed review of how images are meaningfully used. To develop a method to effectively study the flow of design meaning through the use of imagery, it was necessary to develop a method of coding semiotic data. This was achieved by appending the semiotic qualities (icon, index and symbol) to the respective image. This allowed for the statistical quantification of the leading pictorial qualities within the images used. To further complement this, we statistically quantify the semiotic qualities against an established set of design information categories (Suwa & Taversky, 1997). Having quantified the qualitative data, it then becomes possible to statistically analyse and compare the distribution of semiotics used throughout the design task.

Chapter 4 introduces the research methodology and discusses the research design of this study.

Chapter 4: Research methodology and research design

This chapter introduces this study's research methodology and the research design. As illustrated in Chapter 1, this research aims to investigate representation and its role in the generation of meaning in a web-based collective design context. This aim is achieved by using a semiotic and design information-based framework to code and compare representational data collected from an experiment involving an experts' group and a crowd group. In the experiment, a small expert group of designers and a larger crowd group of non-designers concurrently, yet separately, undertake the same design task within an online web-based environment. The two different groups are the main variables in the research.

The goal of this chapter corresponds to the objectives established in Task 1 and Task 2, listed in the opening section. Section 4.1 justifies the chosen research method of using an ODE (Online Design Environment) and semiotics to explore how a crowd will generate design meaning is presented. A pilot study is demonstrated in Section 4.2 to verify and test the ODE in preparation for the main study. The main experiment design is presented in Section 4.3. Lastly Section 4.4 presents the framework for our semiotic-based coding scheme.

4.1 SELECTED METHODS

The strength of any research relies on the application of appropriate methodologies to achieve the research aim. To date there are limited precedents for studying a crowd in design, and secondly there are no precedents for understanding how a crowd will generate design meaning; therefore, the selection of the appropriate methods to fulfil our research aims was critical.

The study of society, crowds and their behaviour is an area of the social sciences closely associated with qualitative research (Kumar, 2011). Methods of qualitative research can allow for an unstructured, flexible and open

approach to enquiry. This method allows the researcher to measure and provide in-depth understanding of cultures and societies and the relationships between the individuals and groups within them (Kumar, 2011). Within the social sciences, this is most often achieved through using a case study approach. Burns (1997) writes that, in order to qualify as a case study, the subject must be treated as a 'bounded system', or an entity within itself. In the current study we are treating a crowd as an entity in itself, and the crowd becomes our bounded system. The case study approach is the leading method for the study of crowds. It is immensely relevant when applied to the understanding of such a bounded system.

For a study of this nature, the organisation, coordination and use of a geographically present (or face-to-face) crowd was unrealistic and logistically difficult to implement in light of the time frame for the current study. Likewise, the data collection from such an approach would incur logistical difficulties. However, social networking websites and the representation-rich content of the web provide the necessary collective conditions for coordinated and concentrated crowd-based activity. The web also hosts many innovations in the form of unique tool suites and programs to users which enable this collective activity to occur.

Methods of qualitative analysis most frequently applied in the design field are neatly summarised by Cross (1999) as including interviews with expert designers, observations and case studies, simulation trials, protocol analysis, reflection and theorising. As this research uses a case study method to understanding how representations are used by a web-based crowd to generate design meaning, it was critical to review and select an appropriate method for data collection. Protocol studies and reflection and theorising are well developed and widely used methods for capturing design information (Cross, 1999; Gero, 2011). However, protocol studies and reflection and theorising have the requirements that rely on video recording, a 'think aloud' design exercise or workshop session to capture the protocol data. This limits the 'thinking-aloud' data to a small sampling pool and, as such, is an inappropriate,

and not to mention logistically unfeasible, approach for a study involving a web-based crowd (Yu & Nickerson, 2011). Not only are techniques such as videoing the designers and asking them to talk aloud impractical in a crowd-oriented scenario, but, as a result of the potential unpredictability of the crowd, it is difficult to select an appropriate method (Rheingold, 2002).

Studies using protocol analysis and observation and interview techniques on students in a studio or workshop setting, while valuable, typically are not equipped, nor have been devised to handle (a) data collection from large or online crowd-centric groups to interpret (b) design-related meaning.

Because this study focuses on how representations are used in the crowd context to generate design meaning, we fill the empirical gaps revealed in this study by adopting a case study approach. The selection of the web-based tool is presented in Section 4.3 and aligns with the objectives of Task 1 (outlined in Section 1.4). There are limited available methodologies for studying crowds in design and no design-specific methods that allow us to review how design meaning is generated with the crowd. Semiotics provides a method for understanding *how* meaning is generated. The semiotic coding scheme developed for capturing, coding and interpreting design-related meaning, as it is generated by a crowd group, is presented in Section 4.4. The development of the coding scheme aligns with the objectives of Task 2 (outlined in Section 1.4).

Design and semiotics share several procedures which are directly related to the function of design representations; they both rely on descriptive notational systems to provide functional and generative content, often in simultaneous combination (Nadin, 1990). Descriptive representations often take the form of precedents or sketches to be recalled for comparative analysis (similar to the signified). These images can be relatively abstract in nature and easily disregarded in the design process in the search for more concrete functional diagrams or information (Wade, 1977). Functional representations are based on defining structural characteristics (similar to the signifier) and more concrete in their nature. Lastly they can be generative; where a knowledge base is constructed to generate new ideas, test, improve, and finalise in design (similar

to the result of the interpretant). The signs that convey contextual meaning in design can be categorised according to how they function in order to convey meaning or act as a cue to initiate further investigation. The use of semiotics in the interpretation of a crowd engaged in design activity within a web environment, is an excellent qualitative approach for dissecting, explaining, and evaluating design meaning conveyed through large amounts of visual information both in design, and design in a web context.

4.2 RESEARCH DESIGN

Based on a review of research methods and recognition of the identified limitations of the individual methodologies most often used in traditional design studies, it was necessary for the research design to meet three critical stages:

- Stage 1) Stage one involved reviewing and selecting an appropriate web-based tool to host openly-shared, online, design activity. The most appropriate web tool would provide the laboratory conditions in which the representation was the leading method for meaningful design information to be expressed. Once selected, an initial task was to conduct a pilot study to determine the viability of the selected environment.
- Stage 2) This stage involves the use two of groups: an experts' group for a benchmark set of data, and a simulated, online crowd. The first group consisted of a minimum of four architects (with no less than five years of design practice and teaching experience). The crowd group was intended to be a larger non-design related group of 18+ participants. Both groups were recruited to participate in a two-week online design experiment. Both groups were asked to explore a conceptual, architectural design task using the same online environment (each group did this separately).

Stage 3) This stage is involved with collating and organising the qualitative data collected from the main experiment. To coordinate the imagery, it was intended that part of this study aimed to develop a coding scheme to draw on the combined principles of C.S. Pierce's semiotics and Suwa and Tversky's (1997) design information categories. The developed coding scheme provided the necessary mechanisms to support the production of an empirical data set allowing for a comparative analysis. In this study, the two different groups are the main variables and the experts' group provides the benchmark data for the comparative analysis with the crowd group.

Stage 1 and Stage 2 correspond to Task 1 as outlined in Section 1.4. Stage 3 corresponds to Tasks 2, 3 and 4 as outlined in Section 1.4. In meeting these three objectives, both groups were provided with the opportunity to generate and use imagery to meaningfully express, test and elaborate on each other's design-related work in an openly shared web-based collective context.

Section 4.3 outlines the selection criteria used in the search for the most suitable tool to act as the ODE. Section 4.4 presents a preliminary suitability test of the selected ODE and discusses the development of a design brief, the data capture capabilities of the selected tool, and provides a summary of the test of the selected online environment. Section 4.6 presents the coding scheme development and Section 4.7 presents the main experiment.

4.3 ONLINE DESIGN ENVIRONMENT SELECTION CRITERIA

Until recently, large scale design experiments to test people engaging in design were prohibitively complex, but web technologies and the organisational structure provided by crowdsourcing now make it feasible to coordinate large numbers of people in design-related exercises (Yu & Nickerson, 2011). Current research into the crowd and its involvement in design has leveraged the environment of online communities who participate in the sequentially combined

and emulated design processes. The study of this phenomenon has focused on the collaborative potential of virtual worlds, such as second life, in support of design (Maher et al., 2010; Yu & Nickerson, 2011). However, virtual environments such as 'second life' are virtual social worlds which aim to be immersive environments and do not specifically support the concentrated richness of digital image-based media required for this study. Similarly, BIM environments support collaboration between experts and the BIM programs such as Revit or ArchiCAD would be prohibitively complex for an average member of a crowd to use. Because there are no collective design online environments, it was vital to select the most appropriate tool for the purpose of adopting and adapting it to suit the needs of this study.

4.3.1 ODE selection criteria

The criteria established were therefore, that the environment needed to be (a) simple to use for any participant and (b) a media-rich web tool. The ability for freely communicating information is a fundamental requisite which must be provided in order to observe any crowd oriented collective activity. It was important to firstly identify a web-based environment that enabled multiple concurrent users with access to an openly shared space in which communication exchanges could occur without restriction. Secondly, the environment needed to support the exchange of a rich and varied range of digital representational media. The selection criteria identified was divided between two main areas: accessibility and functionality.

Accessibility: Accessibility is the overall criteria which consider the ease of use from the perspective of all users. The selection criteria for accessibility were developed during an extensive search for web-based tools. Accessibility is concerned primarily with: ease of access in terms of account establishment versus free to use, simple and easy to use inbuilt tools, and the capability to interact with other users. The overall interface must be usable and demand a negligible learning curve. Accessibility is largely dependent on the consideration for the potential to minimise the learning curve involved in the use of the environment and its tools, and maximise the total time available for the

collection of data in this experiment. As such, the selected tool must yield enough functionality to support collective design that delivers valuable data; while not being prohibitive in terms of complexity. If the tool provided for our participants is too complex, each member of both groups may spend too much time engaging in learning the application. It was decided this would be too detrimental and the design task would suffer as a result, and the data skewed.

Functionality: The selection criteria regarding the ODE functionality was concerned with how well the web-based tool acted as a provisional collective design space. Functional features required included items such as a digital canvas (with the ability to zoom far out and far in), an easy way to insert and resize images and the ability to be shared and viewed by as many who wish to view it. The selection criteria for accessibility were developed in conjunction with the accessibility criterion during an extensive search for web-based tools. Key features of functionality are:

Administration rights: A feature required due to the number of participants involved and a need to keep the data intact regardless of which participant was using the tool selected. For the moderator hosting the design session it was important to maintain the integrity of the data provided without fear of one participant with general privileges to delete data.

Upload and download: Key to our selection of a provisional ODE was the ease with which the provided media could be downloaded and uploaded, and that the type of media it could host had to be wide and varied.

Edit and Save function: Allowing for the effective collection of data was the program's ability to allow users to edit the media provided and to insert fresh media in support of random design arguments or proposals. This was a double-edged sword as the web-based tools reviewed allowed content to be deleted as part of their functions. Naturally, in a crowd context where everybody has to edit to contribute, this could cause concern as editing tools allow for deletion of the entire contents of the experiment.

Shared space, size of space, increase space and area zoom: These features are important to the experiment. In a collective context a large quantity of contributions by the crowd should be accommodated. How the space is shared and zoom in/out functions are of great importance. For participants to provide design-related data, the space needs to be significant enough to hold that data. The space also needs to be viewed and navigated with relative ease.

Chat function interface useability: For the initial stages of the experiment a chat function would allow many participants to discuss and collaborate if they wished. A chat function is beneficial yet not essential in this test.

Drawing tools: These will aid the mark-up and collaborative instances in the experiment. The inclusion is important, as participants will be encouraged to interact within the environment and with the media in any way they see fit, relieving a reliance on inbuilt drawing functionalities.

Responsiveness: This is an included criterion which deals with how well the application responds to input commands. This would include: the ease of cutting and pasting images; how well the drawing tools function; how well the menu system is laid out; and, the practicality for the experiment of the web tool. Some sites are slow and drop out due to connection or server side technical issues. Also, the site may not be highly used and may strain under high data input/output flow when many users are concurrently involved. Our review incorporated noticeable issues at the time of review and did not predict any future issues. Responsiveness is a simple criterion allowing future-proofing of whichever web-based tool was selected for this experiment.

4.3.2 Available platform comparison

To review a selection of tools available on the web an exhaustive review of some of the most popular tools was conducted. The terms of the experiment stipulate that any media can be used in any fashion; therefore, the tool provided should serve to function as the space in which whatever media desired OR selected can be placed for the purpose of sharing, manipulation or exploration. Initially, our search focused on sketch-based tools as the correlation between

sketching and design is obvious; however, a deeper review of sketch-based online tools revealed that there were some significant collaborative limitations, or that the site was taken down. It soon became apparent that the accessibility and functionality we required was not available in the drawing-based online tools. As such, we expanded our search to include presentation tools. Table 4.1 reflects our investigation into both the sketch based tools *and* the online presentation tools.

Table 4.1. Comparative review of available web-based tools.

		FlockDraw	GoogleDraw	Dabbleboard	Scribbleboard	CoSketch	Sketchspace	Scribbler	Prezi	Prezentit	ThinkFree	Zoho Show
REQ's	Currently available	Yes	Yes	No		Yes	No	Yes	Yes	No	Yes	Yes
	Cost	Free	Free			Free		Yes/No	Free/Licence		Fee	Free/Sub
Accessibility	Plugins required	Flash	Unsure			Flash		Flash	Flash		Yes	No
	Ease of access	Yes	Yes			Yes		Yes	Yes		Yes	Yes
Functionality	Requires Account to set up board	No	Yes			No		Yes	Yes		Yes	Yes
	Requires Account to view board	No	No			No		Yes	Yes		Yes	Yes
Functionality	Sharing w/URL	Yes	Yes			Yes		Yes	Yes		No	Yes
	Requires Publishing	No	Yes			No		No	Yes	No	Yes	Yes
Functionality	Max simultaneous users	10	1		6	Unknown		Unlimited	Free/Licence		Fee	Free/Sub
	Max simultaneous viewers	Unlimited	Unlimited		10+	Unknown		Invited	Flash		Yes	No
Functionality	Editable shared content	No	No		Yes	Yes		Yes	Yes		Yes	Yes
	Separate colour code for each user	No	No		No	No		No	Yes		Yes	Yes
Functionality	Edit Tracking	No	No		No	No		No	Yes		Yes	Yes
	Save function	No	Yes		Yes	No		No	Yes		No	Yes
Functionality	Download image from space easily	No	Yes		No	Yes/No		No	Yes	No	Yes	Yes
	Upload image to space easily	No	Yes		Yes	Yes		Yes	Free/Licence		Fee	Free/Sub
Functionality	Add Independent Text boxes easily	Yes	Yes		No	Yes		No	Flash		Yes	No
	Download text box content easily	No	Yes		No	No		No	Yes		No	Yes
Functionality	Clear Board	No	Ctrl + A, Delete		Button	Button		Unknown	No		Yes	No
	Clear board all users	No	No		Yes	Yes		Modest	No		No	Limited
Functionality	Admin function	No	Default user		No	No		Some	No		Yes	Yes
	Shared Space	Yes	No		Yes	Yes		Yes	Yes		Yes	Yes
Functionality	Inbuilt live text chat Functionality	Yes	No		Yes	Yes		Yes	Yes		No	Yes
	Interface Usability	Hard	Ok		Ok	Ok		Good	Good		Unknown	Ok
Functionality	Size of Space	Ok	Good		Good	Good		Good	Excellent		Unknown	Small
	Increase Space	Yes	Yes		Yes	No		No	Yes		Unknown	No
Functionality	Area zoom	No	No		No	No		No	Yes		No	No
	Add another page	No	Yes		Yes	No		No	Yes		Unknown	Yes
Functionality	Highlighting tools	No	Yes		No	No		Yes	No		Yes	Yes
	Colour ink	Yes	Yes		Yes	Yes		Yes	Yes		Yes	Yes
Functionality	Responsiveness	Medium	Good		Medium	Good		unreliable	Can Crash		Unknown	Very Slow

4.3.3 ODE Selection

Of the available web-based applications, Prezi was found to be the most suitable (<https://prezi.com/>). Prezi is online presentation software offering a suitable workspace for a design experiment that is capable of hosting a very large amount of varied digital media. As a presentation tool first and foremost, the primary role of Prezi is to share media rich presentations. The advantage of this, for this study, is that as a result of the functional role of Prezi, all activity may be captured and recorded as a permanent record of activity. In addition to the design activity being permanently recorded within the Prezi shared spaces, Prezi further enables administrators of shared spaces to download the background HTML (Hyper Text Mark-up Language) code. The background HTML code provides a detailed chronological account of all activity. This was advantageous for two reasons; we did not have to rely on adapting traditional data capture methods such as video capture, audio capture and interviews. Furthermore, the interface is intuitive and easy to use, the drawing tools are sufficient but not extensive and Prezi is currently a stable environment with good connection speeds.

Of all of the reviewed web-based applications, Prezi was the only available program that allowed more than two concurrent users in such a graphically dependent program. However, there are some drawbacks to this in that only ten people can concurrently edit while others must watch in the same space and await their turn to edit. Also there are at present no inbuilt chat features, but participants can use the insert text capability and the attached noticeboard to communicate. To use Prezi, it is necessary to establish an account via email in order to use the software, meaning that participants must register to gain access to the design space, and would require a separate set of instructions (See Appendix V. *Experiment participation instructions*).

Upon using the web browser to navigate to the Prezi home page and logging in (Figure 13) the participant will be provided with a simple white screen with a blue circle containing the instructional text 'Click to add text' (Figure 14). The initial white screen is the Prezi digital workspace.

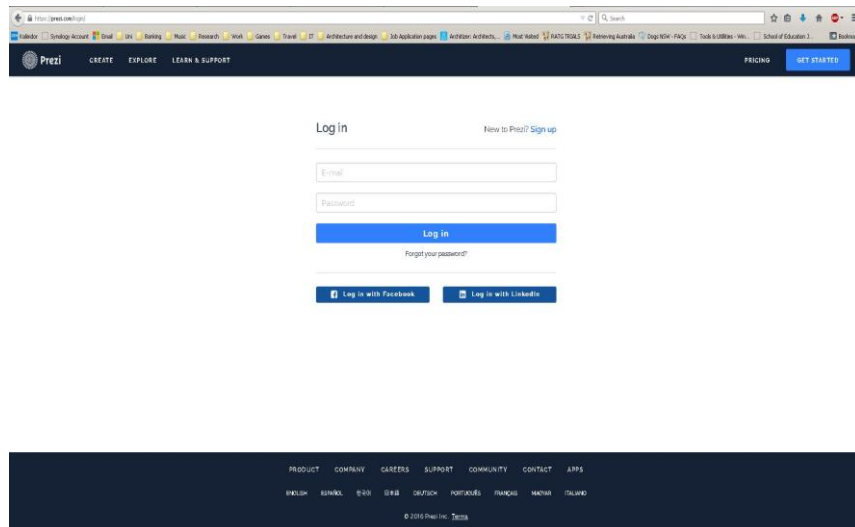


Figure 14 The Prezi home screen and log in screen.

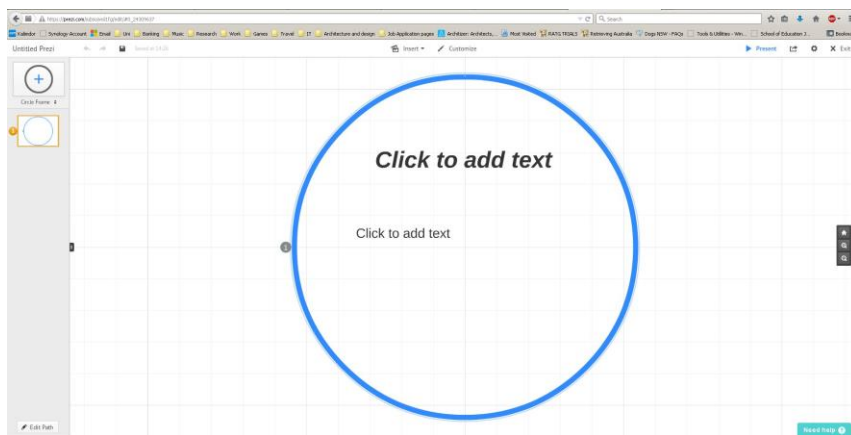


Figure 13 The workspace zoom in and zoom out in Prezi.

¹⁰ All images of Prezi are screenshots generated by the author to illustrate the various pages and demonstrate how the inbuilt tools can be used. Image source: <https://prezi.com>

Part of Prezi's functionality is a very large zoom in–zoom out (any size zoom-out for large scale work) feature, which is achieved using the mouse wheel (keyboard shortcut if no mouse wheel is available is “Ctrl” plus “+” or “-”). Within this space, any type of image-based file can be downloaded or uploaded, including *.pdf documents. This space is a 2D oriented canvas. As there are no 3D functions any 3D related documents are those which are uploaded to aid the designers or the crowd to achieve their design task. By using the text function as a typical text-based instant messaging tool, quick communication is easily achieved (Figure 15).

In summary, using Prezi for a web-based collective design experiment can negate the need to customise traditional methods of data capture such as camera or supplementation or retrospective analysis. All data is provided by the participants and remains visibly recorded within the ODE design space provided. Prezi allows the creator of the space (in our study the space creator is the researcher) to download a *.html text file that provides chronological lists of the time that each image is uploaded and inserted into the ODE. This negates the ‘think aloud’ and video-capturing requirements associated with traditional design-focused protocol studies. Our selected ODE experiment allows the study to run indefinitely, thus providing ample time for observation and data collection.

4.4 SUITABILITY TESTING OF THE SELECTED ODE.

To begin understanding the potential and limitations of conducting a study using Prezi to host the web-based design environment, we initiated a test study by logging into a shared Prezi space. Of the seven volunteers, four actively participated and contributed over three days. One stated there were connection issues and two volunteers cited personal time limits as a reason for not partaking. These participation issues revealed the need for regular moderation in this environment and the potential fluctuation and attrition rates of participant numbers.

You can add text text:
Can I chat using this function.
Yes you can.

Figure 15 Inbuilt text tool as the communication tool in Prezi.

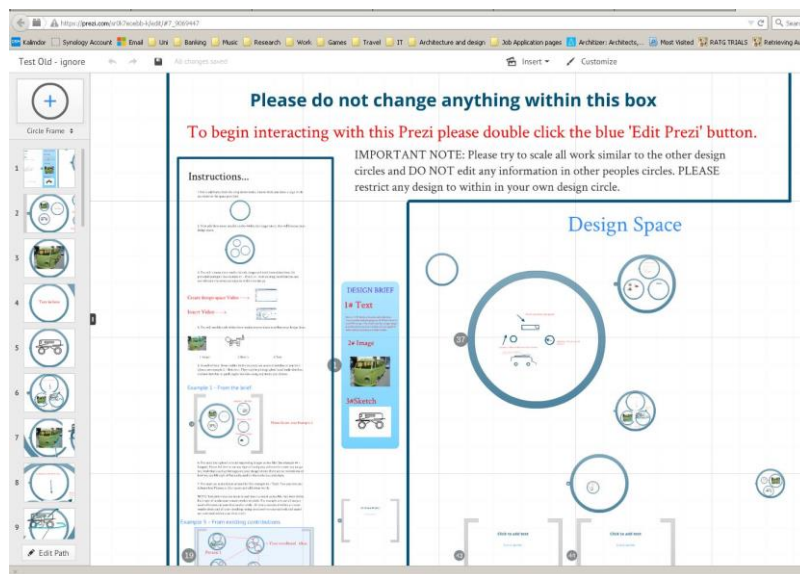


Figure 16 The online design space, with instructions.

¹¹ Image source: Screenshots generated by the author to illustrate the various pages and demonstrate how the inbuilt tools can be used.

Once the participants became Prezi subscribers, it was possible to invite them to shared Prezi space. To test the initial connectivity and accessibility, the subscribed users were then invited via email by the researchers to a shared online Prezi space.

After logging in and joining the shared space, the participants started by familiarising themselves with the environment. The participants were then asked to start uploading a wide range of images to stress test the environment's capacity to accommodate multiple concurrent users (Figure 16). The actively remaining participant volunteers were then asked to provide preliminary feedback on issues such as the ease of joining the shared space and the overall ease of use regarding the inbuilt tools.

Our volunteers stated that there were no immediate issues with logging on to Prezi. Although not a problem to coordinate for a small group, it became evident that to engage a crowd, clear instructions would be needed to organise greater participant numbers, as an expected percentage would be unfamiliar with Prezi. Prezi can at present allow for a maximum of ten concurrent users, with many others able to view. Once our volunteers accessed the shared space they were able to intuitively and quickly familiarise themselves with both the environment and the rudimentary tools. Feedback indicated that the tools were easy to find and the process of uploading images and commenting was easy to achieve by using the inbuilt menu system. However, our participants raised questions regarding how to safeguard their work in this open environment from being deleted by other users. As a result, it was determined that not only was moderation required but editing rights needed to be restricted to the participant's own work, except for the act of copying and commenting on others' work.

4.4.1 Developing the design brief

After the participants were comfortable logging in and navigating the environment, the researchers introduced a small design-related task. The task was designed to simulate a design brief with the intention of stimulating the

observable design activity of the active participants. This was intended to provide the researchers with the opportunity to evaluate the environment's suitability to host design activity. Gagne (1959) stated over 45 years ago that problem solving begins with a stimulus situation (as quoted by Lau, 2007). Darke (1979) proposed the primary generator as the stimulus for design activity due to a set of informational requirements prompting a design cycle. The design cycle is often simply described as analysis, synthesis, and evaluation (Roozenburg & Eekels, 1995) and as a more iterative and reflective design process by Schön (1983). In order to try and stimulate activity that may reflect either analytical or iterative, or both types of problem-solving behaviour in our non-design participants, it was decided that the first design brief should be built around familiar concepts. By starting with a rudimentary task, the researchers were provided with the scope for ongoing development of the brief until it was suitable for (a) the environment, (b) the task and (c) the suitability for stimulation of design-related activity in both groups in the main experiment.

As a starting point, a brief was presented using three components; text, image and a sketch. A small block of text provided a description of what was required. It outlined that we required design ideas for an off-road, four-wheel drive camper van. Next to this was an image of a small green Volkswagen camper van that was an unfinished restoration project. Lastly we provided a small sketch created within Prezi to indicate to our volunteers that drawing tools were available (Figure 17).

We instructed the participants to use, in any way they wish, the provided text, image and sketch as a basis to start exploring ideas centred on the 4x4 camper van design-related theme. Initially there were many recurring questions regarding how the participants were to engage with the task, what was required and what to do. Based on the initial observations and by working closely with the four volunteer participants, the feedback indicated that it was important to include detailed instructions upon first entering the Prezi design space.



Figure 17 The design brief with example image and sketch.

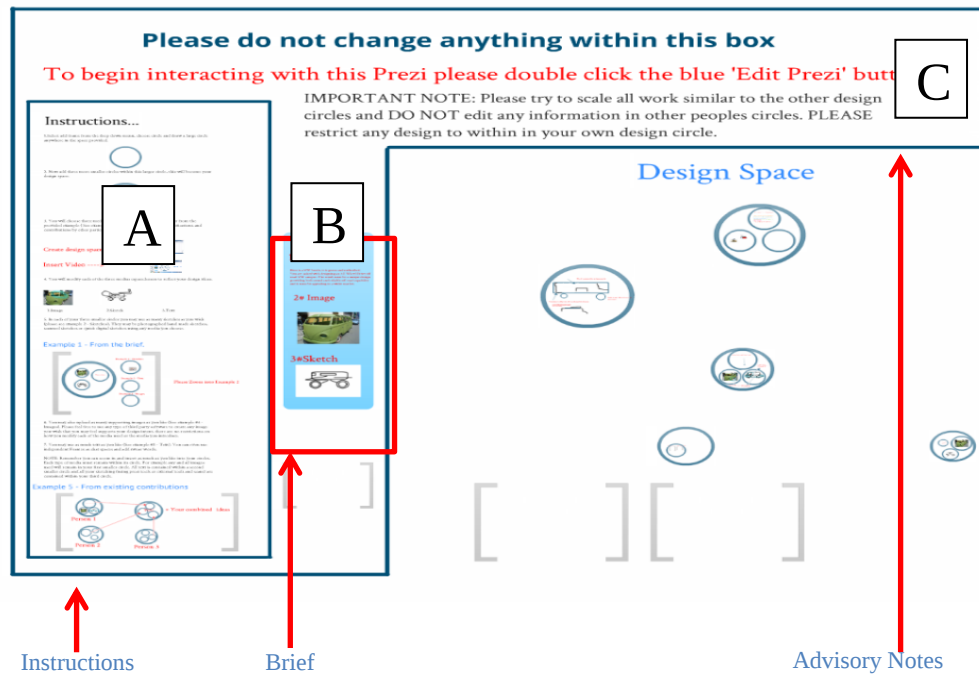


Figure 18 The design space with Instructions (A), Brief (B), and Notes (C).

¹² Image source: All images of Prezi and the experiment settings are screenshots generated by the author.

As a result of the preliminary observations and feedback, a set of detailed and concise instructions were developed. These instructions became the start screen for each individual user (Figure 18).

These instructions were included in the brief and a small number of rules such as asking the users to keep their work within a large circle (defining a space as theirs within the larger Prezi space) and not to delete other participants' work. Over 12 hours the volunteers were able to upload images and start work within their design circle. As this was an ongoing pilot study we were able to immediately adjust and further refine the instructions as needed. This allowed us to continue to observe and evaluate the capabilities of the environment as well as continually develop a design brief that might stimulate activity of experts and novices in a main experiment. This portion of the pilot test was conducted between 19/12/2012 and 14/01/2013 and provided, through observation, an initial set of insights regarding the support for the type of online design activity that might occur under such conditions.

4.4.2 ODE data capture capabilities

The participants had little issue following the instructions and even less issue in contributing a response to the design brief. As this test was limited to the contributions from four active participants, the introduction of separately drawn hand sketches was not as yet evident, as was the mixing of ideas. However, in some cases, unique ideas were presented using representations and interaction with representations was observed in this exploration of the design task.

Part of the functionality offered by Prezi is its capability to act, for the researcher, as a data capture tool. Moreover it is also possible to download the entire Prezi as a HTML script. This is of extremely high value to the design researcher as it allows direct access to a chronological record of how the images are used. This is achieved by the automatic numeric tagging of the image to reflect the order in which the images were inserted into the Prezi space. This high level of flexible interactivity allows for the collection of a rich

and varied representational data set. As Prezi is a representation-based web tool, it is by proxy a screen-capturing program in itself that is well suited to a design study of this nature. Using Prezi as a temporary design space in this manner a permanent record of activity that occurs within the program was created.

4.4.3 Summary and results of the test study

The observations of the pilot design test were unstructured and limited. However, an initial observational review enabled us to abstract and verify that the identified representational components in our conceptualisation were a suitable basis for further study.

Overall there were no immediately recognised difficulties in using Prezi as a workspace for web-based design activity. Connectivity was good and latency (time for online events to happen) was high. It was recognised during the testing that participant numbers might fluctuate within the crowd group, indicating the need for a study to run over an extended length of time. Prezi allows users to leave and return at their will. This might present a scenario whereby users would log out one day to return another day to find that other users have logged in and developed the design or used their representations.

The initial observations taken during the test study revealed that the contributions of individuals remained isolated to within their design circle. In larger groups and crowds, the range in behaviours naturally increases which contributes to the diversity of the participants' range (Surowiecki, 2004). As a result of the increased behavioural diversity it is estimated that a percentage of the participants—within a larger main experiment—may engage in exploring other participants' contributions. With this there is potential for the initiation of a dispersed activity to produce shared knowledge or an idea. The capture of representational data occurs naturally. All activity is permanently recorded by default, providing permanent access for the researcher in order to extrapolate all contributions for coding at a later date. Through observing the combined

activity in our test study it was possible to conclude that Prezi was a suitable tool for capturing design-related representational data.

4.4.4 Considerations based on the pilot study results

The purpose of the pilot study was not to prematurely draw conclusions about crowd-based design, but to test whether the research design and research environment was effective for the purpose of a much larger main study. The results of the pilot study suggested that the experiment setting is achievable on the practical level and well serves the research aim. Other issues that were identified as being significant for the main study were as follows:

- **Definition of a crowd:** In order to define the web crowd for our experiment, we have identified that the top-down approach of subjectively, numerically defining a large number of participants is not suitable. The approximating involved in recreating the diversity of the crowd in the laboratory environment cannot be recreated genuinely through careful selection of group members, as the research requires a true reflection of participation of a genuine crowd, and selection of members would invalidate this group mix. Instead, we will use a bottom-up approach to raise awareness and propagate interest to directly generate a crowd of Internet-based participants. The digitally decentralised domain of the Internet presents us with the opportunity to tap into and access a portion of an immediately available global crowd. It is the participants who engage with the experiment, as a result of the awareness generated through the recruitment process, who will ultimately define the numbers that constitute our crowd. Any crowd by definition represents a wide cross pollination of design-related capabilities; as a result, it is not known what design problem-solving heuristics a web crowd will leverage when compared to traditional approaches to design used by experts.
- **Crowd productivity:** Our crowd may produce nothing. As unpredictability is an inherent quality of crowd behaviour, shaping

the outcomes of the crowd's intelligence depends on how we define the crowd and how they are motivated. It is entirely plausible that, given the lack of formal design experience coupled with the freedom offered by the environment, that a crowd's involvement in this experiment may not produce any data of value. In this scenario, the only participants to produce design-related data may be the professional design group. This may highlight the need for presenting the design to the crowd using a balanced approach, combining mediation with design freedom.

- **Environment familiarisation.** Prior to engaging in the experiment in the Prezi environment, participants will be advised to familiarise themselves with the program. The preliminary results indicated it is very easy to use, even for those who have never encountered the Prezi tool, and requires minimal effort to learn. It is hoped that through prior exposure and sufficient instruction, there will be limited superfluous familiarisation with related representational data produced. Instructions will be provided prior to engaging with the experiment information statement. These same instructions will also be clearly on display within the Prezi space throughout the main experiment.

From the results of the pilot study, we can see that the chosen online design environment (Prezi) can support both multiple representation types and multiple participants concurrently. It contains the functionality to support online design activity for both an experts' group and a crowd's group, and therefore it can generate meaningful results for a comparison in the current study. After addressing the problems mentioned above, our next goal was to develop a coding scheme to handle the representation-based data. Our coding scheme development is presented in the following section (Section 4.4).

4.5 CODING SCHEME DEVELOPMENT

The development of the coding scheme used for this dissertation was according to the objective outlined in Task 2 of the research aims and objectives (Section 1.4).

As the methods of data capture traditionally associated with design research are not suited to capturing the information flow within the newer web-based environments, there is a need for an effective method which can both capture the initial body of design meaning, and the changing over time flow of meaningful design content. Typically, due to the conditions provided by the selected ODE, all activity was permanently captured; this was advantageous as it presented researchers with inbuilt data capture facilities. By organising and coordinating this permanently stored record of activity it became possible to organically develop a coding scheme based on the use of the representations within the provided design context. In this section, the main elements of the published manuscript titled *A method to code shifting semiotic states in design* are presented. The following coding scheme was developed in three parts which, when combined, make up the coding scheme in its entirety. The development of the coding scheme is presented in three parts, they are:

Part 1: Coded semiotic values: Section 4.4.1 describes how the coding scheme captures the semiotic values of the imagery used. This operates on two contexts: a general semiotic context and a design semiotic context. In the general context the representation carries nothing but its own meaning prior to being used in a design context. Once contextualised by a design brief, the semiotic context becomes design-related context.

Part 2: Coding the semiotic movement: Section 4.4.2 describes how the coding scheme captures the movement of design meaning. Section 4.3.2 presents the coding scheme as a formal method for applying semiotics to code the flow of design meaning when it occurs within a media rich online environment.

Part 3: Coding the design information categories: Section 4.4.3 describes how the coding scheme captures the design-related informational content of the selected images. This draws upon Suwa and Tversky's (1997) design information categories to organise the informational content of the images.

With the above described elements combined, the coding scheme aims to capture movement of design meaning by coding the semiotic values, their shifting states and their design-related informational content. In developing this coding scheme it becomes possible to quantify qualitative data for the purpose of producing an empirical data set in relation to semiotic and design-related information.

4.5.1 Part 1 Coding semiotic values.

The most direct definition of semiotics is that it is the study of signs. Early in modern semiotics signs include images, words, gestures and objects (Chandler, 2002). These signs are not studied in isolation but as part of 'sign systems'. Sign systems allow us to investigate how meaning is generated and how reality is represented through varying forms, and combinations of text and media. At its core, semiotic theory is a framework in which three types of *sign* can be categorised, depending on how they allow for comprehension. These categories are icons, indexes, and symbols. The *Icon*, *Index* and *Symbol* provide a co-ordinated way of talking about how meaning is expressed via the relationship between Representamen (the form a sign takes), Object (entity to which the sign points), and Interpretant (qualities expressed by the representamen) (Chapman, 2004; DeGrassi, 2008; Everaert-Desmedt, 2011).

Icons: (Figure 19) in a general context, represent the 'signified' by virtue of similarity, and work by imitating the visual features of the object that it is representing. The icon closely resembles what is being represented. The icon is defined as the representation which possesses some of the signified qualities: e.g. a photograph, a portrait or sound in movies and pictorial simplifications of trees (Chandler, 2002).

Index: (Figure 20) in a general context conveys a relationship between the signifier and the signified. The index is a mode of representation where the signifier is not arbitrary but directly connected in some way. Common examples are footprints, smoke, lipstick or ultra-scans (Chandler, 2002). Although the actual subject relates to a human, the human is only implicit in the image. The presence of the footprint or image of the lipstick directly connects the image to a person who would have created the print.

Symbols: (Figure 21) do not resemble the signifier. Any connection to what is being represented is purely conventional (Chandler, 2002) and, in a general context, operate not by using visual or conceptual connections to the signified, but through a socially established convention (i.e. something that has to be learned before the meaning of the symbol can be understood) (Chandler, 2005; Chapman, 2004; Pierce, 1982).

Icon, index, and symbol are not so much different types of *sign* as they are different *principles* that serve to bind a certain signified to a given signifier. There can easily be two or even three of these principles used together in any sign. For example Google Earth (Figure 22) is a mixture of representational forms and can be read as: indexical satellite images; iconic road maps; or symbolic nation-state boundaries (Helmerich, 2011).

Another example of an unmanipulated photograph (as a signifier), is frequently linked to its subject (the signified) both indexically and iconically at the same time. That is, a photograph of a man is an iconic sign of that man inasmuch as it resembles him. It is also an indexical sign of that man because the photograph was originally physically contiguous with him: the man had to be there, in front of the lens at the time the shutter was opened, to be captured on film (Cramer, n.d).

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Figure 19 Icons work by directly referencing the subject.



Figure 20 Index works by indirectly referencing the subject.

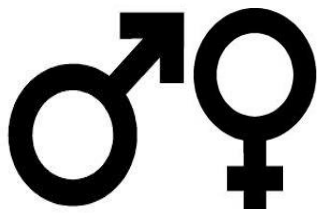


Figure 21 Symbols must be learnt in order to interpret.

¹³ The analysis of signs according to these three principles can become nuanced. Peirce himself formulated a bewildering variety of subtypes and sub-subtypes, and the classifications are not mutually exclusive. An undoctored photograph (as a signifier - Figure 19) is frequently linked to its subject (the signified) both indexically and iconically at the same time. Regardless of the nuances the founding triad of Peirce's system is very simple. The selected images are openly available by internet searching Icon, Index and Symbol related images.



Figure 22 Google map overlay with all semiotic classes combined.

¹⁴ Image source: Image captured from Google Maps.

Lastly, it is not uncommon for multiple signifiers to be present in one image. Semiotics is a method that is widely used for analysing signs in images and provides a formalised interpretive framework for disseminating the meaning they contain. However, before applying semiotics, to design we must recognise that semiotics is context dependent. That is, the meaning any image carries is largely dependent on the context in which it is used. This being the case, we refer to any representation such as the examples provided above as general semiotics; general, as in they have not been used within a design conversation to express design-related meaning. Any images created or applied to generate design meaning, we refer to as semiotics in a design context. In design as well as semiotics, the main objective of generating representational signs is to encode information about the physical object which is being designed. This allows other designers or participants to decode the information and turn the represented idea into an abstracted reality (Ashwin, 1984).

To this end, signs used in the design process signify the contextual information conveying meaning in regards to the object that is the focus of the design process. Semiotics and design share several procedures that are directly related to generation of contextual meaning; they both rely on descriptive content to be functional and generative—often in simultaneous combination. Descriptive representations often take the form of precedents or sketches to be recalled for comparative analysis (similar to the signified). These images can be relatively abstract in nature and easily disregarded in the design process in the search for more concrete functional diagrams or information (Wade, 1977). Functional representations are based on defining structural characteristics (similar to the signifier) and are more concrete in their nature. Lastly they can be generative—where a knowledge base is constructed to generate new ideas, test, improve, and finalise in design (similar to the result of the interpretant).

Signs that convey meaning can be categorised according to how they function in order to convey design meaning or act as a cue in initiating further investigation. Semiotics is context dependent; therefore coding the icon, index and symbol when used in generating design meaning as a representation used

in a design context will enable us to meaningfully organise our design-related semiotic information. Following is a description of the types of Icon, Index and Symbol used in a design context:

Icons: (Figure 23) in a design context still adhere to normal semiotic rules. They represent the 'signified' through the use of similarity and work by imitating the visual features of the object that is being represented. To qualify as an icon in design, they must closely resemble what is being represented. As such what is being represented must exist.

Index: (Figure 24) in a design context contains similar visual qualities as the icon; however, contrary to the icon, what is being represented does *not* yet exist. Although the actual signified object cannot be physically present, the presence of the image directly connects the image to the design intention. In a design context, the drawing or rendering which depicts a potential building, although possessing iconic qualities, cannot be considered an icon as per normal semiotic rules and only an index to what potentially *can* be.

Symbol: (Figure 25) in a design context operates according to normal semiotic rules, i.e. they are understood by having pre-learned a conventionalised set of rules (Chandler, 2005; Chapman, 2004; Pierce, 1982). A symbol is a signifier which does not resemble the signified and is fundamentally arbitrary or conventional (Chandler, 2002). For example, design drawings such as plans, sections and elevations are heavily embedded with multiple conventional symbols that describe wall size, materials, and openings. But in reality these are an arbitrary relation as to what is actually being signified.

The signs that convey meaning can be categorised differently according to how they function within their applied context. Taking into account the contextual characteristics of semiotics, two levels of imagery were selected for coding: general semiotics and design semiotics.



Figure 23 Iconic images that can be associated with design.

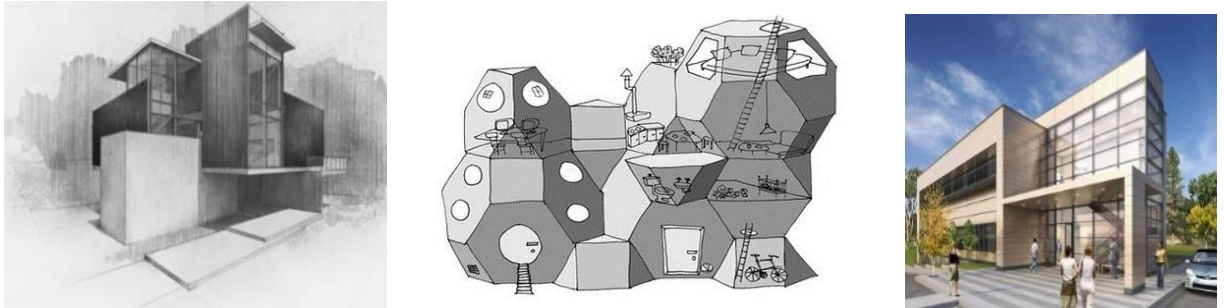


Figure 24 Indexical images often seen in design.

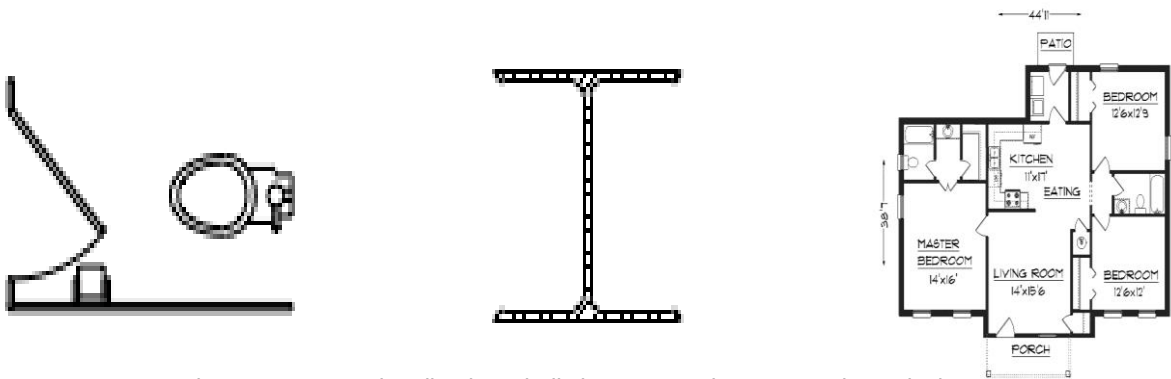


Figure 25 Conventionalised symbolic images used to communicate design.

¹⁵ The selected images are generic images and are openly available by internet searching for architecturally related images.

The term ‘general semiotics’ is used in this dissertation to describe the image and its prior intended meaning (where known) or function; that is, before being brought into a design context. The signs that convey contextual meaning in a design context can be numerically categorised differently, according to how they potentially function indefinitely within the design context in order to convey design meaning or act as a cue in initiating further investigation.

Design semiotics is therefore used in this study to describe the image after it has been recontextualised to convey design meaning. Having been recontextualised from a general to a design context, the original meaning will undergo a movement from an original general non-design related value to a design related value. This movement is captured as a transition. Section 4.5.2 presents a coding scheme that captures the semiotic values described in this section and the movement of design meaning as the representations are engaged with in the ODE. Section 4.5.3 describes how we combine semiotic values with the informational content and the movement of design meaning within the ODE.

4.5.2 Part 2 Coding semiotic movement.

The main objective of generating representational signs in design is to encode meaningful information so that it might be communicated. To capture the movement of meaningful information, this study begins with two examples. As a starting point, the semiotic qualities of the images used are considered prior to being used for design meaning because, as such, these prior values are counted as general semiotics (**Sg**). Having been introduced into the experiment environment to convey design meaning, the semiotics become bound to a design related context (**Sd⁽¹⁾**). We numerically categorise the movement between and within these contexts as transitions (**Tr⁽ⁿ⁾**) (Figure 26).

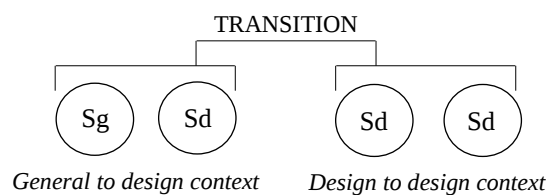


Figure 26 Contexts for semiotic transitions - general and design contexts

Due to the experimental setting and structure in this study, the representational imagery used between a general context to design context is a once only transition ($Sg \rightarrow Sd^{(1)}$). Any further interactions based on imagery already present within the experiment setting are transitions that occur in the $Sd^{(1)} \rightarrow Sd^{(2)}$ context and are potentially recurring ($Sd^{(1)} \rightarrow Sd^{(2)} \rightarrow Sd^{(3)} \rightarrow Sd^{(4)} \rightarrow \dots$) (Figure 27) depending on the extent of the interactions that arise centred on that image.

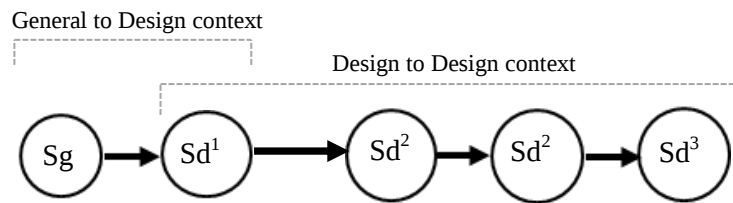


Figure 27 Transitions from general to design context and within design contexts.

When the meaning in any given image is changed through contextualisation, a shift will occur from what the icon, index or symbol originally *signified* to a new or an additional *signified* meaning. Such changes in meaning can be identified according to the *type* of semiotic combination they transition ($Tr^{(n)}$) from and to. Involved in the movement between each context (Sg or $Sd^{(n)}$) there are 42 possible types of transition that can occur. Each of the 42 types of $Tr^{(n)}$ are divided across six types of transitional movement (Type 1 to 6). Within each of the six types of transition are seven potential combinations. The transition between $Sg \rightarrow Sd^{(1)}$ or $Sd^{(1)} \rightarrow Sd^{(2)}$ can be transcribed as: $Tr^{(n)} = Type^{(1)} \text{ No. } 1$ ($Sg \text{ (or) } Sd^{(n)}_{(Icon, Index, Symbol)} \rightarrow (Sd^{(n)}_{(Icon, Index, Symbol)})$). The potential types of combinations are presented in the following Table 4.2 (p.96).

Table 4.2 All potential combinations of semiotic transitions.

TRANSITION TYPES		
Type 1		Type 2
1	Icon $\rightarrow$ Icon	Index $\rightarrow$ Index
2	Icon $\rightarrow$ Index	Index $\rightarrow$ Icon
3	Icon $\rightarrow$ Symbol	Index $\rightarrow$ Symbol
4	Icon $\rightarrow$ Icon + Index	Index $\rightarrow$ Icon + Index
5	Icon $\rightarrow$ Icon + Symbol	Index $\rightarrow$ Icon + Symbol
6	Icon $\rightarrow$ Index + Symbol	Index $\rightarrow$ Index + Symbol
7	Icon $\rightarrow$ Icon + Index + Symbol	Index $\rightarrow$ Icon + Index + Symbol
Type 3		Type 4
1	Symbol $\rightarrow$ Symbol	Icon + Index $\rightarrow$ Icon
2	Symbol $\rightarrow$ Icon	Icon + Index $\rightarrow$ Index
3	Symbol $\rightarrow$ Index	Icon + Index $\rightarrow$ Symbol
4	Symbol $\rightarrow$ Icon + Index	Icon + Index $\rightarrow$ Icon + Index
5	Symbol $\rightarrow$ Icon + Symbol	Icon + Index $\rightarrow$ Icon + Symbol
6	Symbol $\rightarrow$ Index + Symbol	Icon + Index $\rightarrow$ Index + Symbol
7	Symbol $\rightarrow$ Icon + Index + Symbol	Icon + Index $\rightarrow$ Icon + Index + Symbol
Type 5		Type 6
1	Index + Symbol $\rightarrow$ Icon	Icon + Index + Symbol $\rightarrow$ Icon
2	Index + Symbol $\rightarrow$ Index	Icon + Index + Symbol $\rightarrow$ Index
3	Index + Symbol $\rightarrow$ Symbol	Icon + Index + Symbol $\rightarrow$ Symbol
4	Index + Symbol $\rightarrow$ Icon + Index	Icon + Index + Symbol $\rightarrow$ Icon + Index
5	Index + Symbol $\rightarrow$ Icon + Symbol	Icon + Index + Symbol $\rightarrow$ Icon + Symbol
6	Index + Symbol $\rightarrow$ Index + Symbol	Icon + Index + Symbol $\rightarrow$ Index + Symbol
7	Index + Symbol $\rightarrow$ Icon + Index + Symbol	Icon + Index + Symbol $\rightarrow$ Icon + Index + Symbol

In this study we are interested in capturing the flow of design meaning when imagery is introduced in both the initial $Tr^{(n)} = (Sg_{(x)} \rightarrow Sd^{(n)}_{(x)})$ and the movement of meaning throughout the subsequent design activity $Tr^{(n)} = (Sd^{(n)}_{(x)} \rightarrow Sd^{(n)}_{(x)})$ (Figure 28).

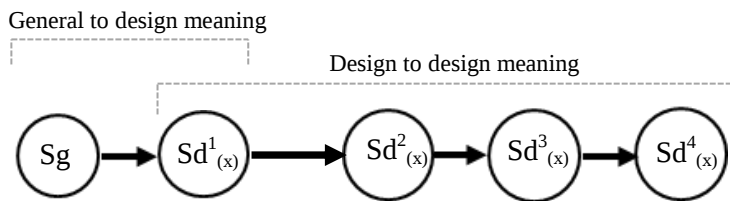


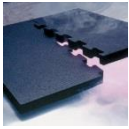
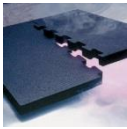
Figure 28 Semiotic transitions - general to design and design to design contexts.

Example $Tr^{(n)} = \text{Type 1 No.6} - Sg_{(x)} \rightarrow Sd^{(1)}_{(x)}$

The representation in Table 4.3 is a safety mat taken from a website. In its original state it is a general semiotic icon ($Sg_{(icon)}$). As there is a generation of meaningful design information based on the introduction of this image, we can code the entire transition as the first ($Tr^{(1)}$). It is the first transition because the original qualities of the image are borrowed and the original meaning now

transitions from the general semiotic context (Sg) to its new design meaning within a design-related context ($Sd^{(1)}$). An annotation with the image indicated a derived behaviour that denoted a clicking-style connector that joined living modules together. As the mechanism does not exist, the original icon now has a new semiotic value that functions to communicate meaning via indexical and symbolic semiotic values. The image now indexically represents a connection with the image, symbolic of the connection method. By representing a design idea, the changing semiotic value is captured, as the transition that occurs was between the original state ($Sg_{(icon)}$) to a new semiotic state ($Sd_{(Index+symbol)}$).

Table 4.3 Transition from general semiotics to design semiotics.

Transition 1			
Type⁽¹⁾ No.6 = $Sg_{(icon)} \rightarrow Sd^{(1)}_{(Index+symbol)}$			
	Safety Mats		Zip mechanism to join units
Icon	Original Meaning (Sg)	Index-Symbol	New Meaning ($Sd^{(1)}$)

Using our semiotic coding scheme we can transcribe the example transition in Table 4.3 as:

$$Tr^{(1)} = Type^{(1)} No.6 \in Sg_{(Icon)} \rightarrow Sd^{(1)}_{(Index, Symbol)}.$$

Example $Tr^{(n)} = Type\ 1\ No.2 - Sd^{(1)}_{(x)} \rightarrow Sd^{(2)}_{(x)}$

The movement of meaningful information between design-related context is written as $Sd^{(1)} \rightarrow Sd^{(2)}$ and it is the second of the two identified contexts (Sg and Sd respectively). The $Sd \rightarrow Sd$ transition will allow for the tracking of the semiotic flow of meaning within a design context. The stack of shipping containers (Table 4.4) has been introduced previously (from $Sg \rightarrow Sd^{(1)}$) and was used to denote a stacking characteristic as a precedent ($Sd^{(1)}_{(Icon)}$). This image was then annotated by another participant whose focus was on interlocking the units that, in that participant's particular words 'piggyback' an existing, in situ infrastructure. The $Sd^{(1)}_{(Icon)}$ has now undergone its second contextualised transition to $Sd^{(2)}$ and its additional meaning communicates functions in an indexical capacity $Sd^{(2)}_{(Index)}$.

Table 4.4 Example Sd (1,2,3,4...) to Sd (2,3,4,5...).

Transition 2			
Type 1 = Sd ⁽¹⁾ _(icon) → No.2 = Sd ⁽²⁾ _(index)			
	"Stacked housing"		"Piggyback existing infrastructure"
Icon	Original Meaning (Sd)	Index	New meaning (Sd)

Using our semiotic coding scheme we can transcribe the example transition in Table 4.2 as:

$$Tr^{(n)} = Type^{(1)} No.2 \in Sd^{(1)}_{(Icon)} \rightarrow Sd^{(2)}_{(Index)}.$$

Coding the associated movement of information as a transition as described in Table 4.5 will allow us to track the changes in meaning as they occur over time. Coding the movement of information in such a manner allows us to formalize the criteria for the semiotic movement of design information. As such, we can formally account the iterative time-based and transitional nature of the meaningful information flow within the online-based design processes in a general and design related set of semiotic contexts.

Table 4.5 Example of the tabularised coded semiotic values across contexts.

General Semiotics -Sg					Design Semiotics Sd ⁽¹⁾				Design Semiotics Sd ⁽²⁾			
CIRCLE		Ic	In	Sy	Type ⁽ⁿ⁾ No. ⁽ⁿ⁾	Ic	In	Sy	Type ⁽ⁿ⁾ No. ⁽ⁿ⁾	Ic	In	Sy
		X			1-3			X	3-3			X
			X		2-1		X		2-3			X
		X			1-2		X		2-1		X	
			X		2-1		X		2-3			X

4.5.3 Part 3 Coding design information categories.

To understand how representations are used to generate design meaning in our web-based crowd context, it is important to be able to categorise the design-related content of the image.

Larkin and Simon (1987) and Suwa and Tversky (1997), have suggested the pictorial devices for expressing meanings and concepts in design consist of: (a)

depicted elements, such as objects, spaces or icons; and, (b) their spatial arrangements. These summaries of design-related information, conveyed visually, are the distilled result of extensive protocol studies of designers sketching in action, and design theories. In their 1997 study of designers and their sketches Suwa and Tversky (1997) outlined four major informational categories, each containing a number of subclasses of information. The four major categories are: depicted elements, spatial relations, abstract relations and background knowledge.

Although the presented four major categories were developed primarily in relation to the study of sketching in design, they are equally applicable to other visual media for their organisational value regarding the informational content of digital representations. This provides a cataloguing method which is highly relevant to this study. In this study the four major domains of design information are described as: depicted elements, spatial relations, abstract relations and background knowledge. They are adopted and extend with the addition of an extra domain of design information which is categorised as a technical domain. As Suwa and Tversky (1997) investigated designers and students, their subjects all came from a design background and thus had some understanding of what needed to be considered and when. However, a web-based group are not expected, or at present, able to re-enact this collaborative sketch based activity in the experiment environment. Nor are all people in a crowd considered to uniformly possess the same design experience. This being the case, the information within the domains of informational categories may vary significantly from that of experts or student designers. However, it is highly likely that the individual within the crowd might exhibit novice designer characteristics and not approach the design task systematically, instead, reason backwards and deductively, and offer general final ideas and construction ideas early on (Ericson, 1997; Zeitz, 1997). By characterising the images used, using the design information categories, it becomes possible to identify the design-related content of the image regardless of the experience of the individual providing the image and the meaning. In addition, it becomes possible to catalogue and organise each image during the course of the experiment alongside its

corresponding semiotic value. By combining the semiotic values alongside design information categories, it is possible to determine methodically what the intended meaning is and how it is constructed. This result of coding the qualitative representational data produces the quantitative data necessary for a statistical analysis. The development of the coding scheme is undertaken according to Task 2, as outlined in Section 1.4.

The addition of a technical domain category as an additional major category was to enable us to cope with technically related sets of representations and meaning provided by the crowd. The extensions to the subclasses of information take the form of minor additions to Suwa and Tversky's (1997) existing table, and as such, the original subclass information remains unchanged. Examples of the major categories and subclass categories are outlined in the following Table 4.6.

Table 4.6 Design information categories and their related subclasses.

Major Category	Subclass	Examples
Properties	Spaces	Sample images of interior/exterior spaces.
	Things	Light dome, Wind turbine, Water Tank, Solar Panel.
	Features	"it should have/be" Green wall, Koi Pond, Skylights etc.
	Materials	Bottles, Card, paper, Wooden Pallets, Glass, Wood and Metal.
Spatial	Local Relation	How elements relate to each other, how arranged, fit /could fit together.
	Global Relation	The overall Configuration of spaces or elements, orientation, spatial relation. Site context and environment related information.
Functional	Practical Roles	Scale, Resource, human scale, "Living space should be" Disused car parks office spaces. Transportable units. The practical role of any structure or object.
	Activity	"Somewhere to sleep, eat, clean" – Bedrooms, living and bathrooms, movement within spaces.
	Abstract Features	Warmth, health, Insulation, energy, Waste.
	Views	Physical / digital images focusing on visual qualities such as how it might look.
Technical	Construction Method	How it's built, can be built, or put together.
	Component	Prefabricated elements and items used for/in construction of structure
	Diagram	Physical / digital Drawings and diagrams used to explain ideas, or construction method.
Background knowledge	Domain Knowledge	Examples of existing concepts, structures and materials combined to perform specific function. Precedents.
	Metaphor	Abstract Images or representations used to describe technical or conceptual information, ideas or social contexts.
	Text	Written or images of written material used describe factual, conceptual or technical information ideas or social contexts.
	Light	Interaction, objects where consideration of light is central.
	Reflective	Symbols or Diagrams indicating a thought process, consideration or requirement.

¹⁶ **Properties:** The category of 'properties' remains consistent with Suwa and

¹⁶ The first major informational category described by Suwa and Tversky (1997) is depicted elements. Through the enactment of depicting properties through sketching shapes, lines, places, areas and volumes, design emerges (Suwa & Tversky, 1997). Since there are no facilities for the traditional enactment of sketching or drawing in Prezi, the sketch, in the context of Suwa and Tversky (1997), is not consistent with the media that might be used in a web-based design study for the emergence of design. In light of the experiment setting, the inclusion of contemporary rich visual media provides an opportunity to adopt and extend Suwa and Tversky's (1997) depicted properties information category. Renaming depicted elements to properties allows for the extension of this information category to include any type of visual media will enable the capture of descriptive properties as they might be described in a web-based design experiment when not limited to sketching.

Tversky's (1997) original informational content. For the purpose of this study the characteristic of properties is to describe the content of any type of image that is refers to elements such as spaces, areas, features, items and any general objects and properties deemed relevant to the design task.

Properties subclasses: The major category of properties is divided into four subclasses: Spaces, Things, Features and Materials. Spaces refer to the visual qualities that predominantly describe types of space, such as shape and size, volume and relationships between spaces. Things are images of complete objects without any other imagery present. Items counted as things are light domes, wind turbines, water tanks, and solar panels. To categorise these images they are generalised according to what they represent in their standalone nature. For example, an image of a light dome as a standalone image was considered a thing at a base level. Features are typically identified as additional embellishments to spaces such as green walls or Koi ponds, as well as expressing qualities such as transportability and affordability. In this study the properties subclass is extended to include materials. Materials specifically denote the use of images for the sole purpose of explicitly communicating types of material, the range of which can include any material ranging from recycled card, paper or plastic, to standard building materials.

¹⁷ **Spatial relations:** Spatial relations are referring to the emerging visual features of the properties. Suwa and Tversky (1997) note that architects and designers can see the spatial relations in their own sketches, much like the properties of depicted elements. Since there are no facilities for the traditional enactment of sketching or drawing in the experiment environment, emergence from depicted properties according to Suwa and Taversky's (1997) definition of arising from sketching activity is unlikely to occur. This will be as a result of the rudimentary nature of the drawing tools within Prezi. Any design emergence that does occur most likely would be derived from, and communicated through, the use of imported imagery. In Suwa and Tversky's (1997) study, the spatial

¹⁷ Refer to Table 4.6.

relations category is concerned with the emerging spatial arrangements of objects and spaces as they arise during the process of design. This domain of information is embodied by two subclasses; a local relation and a global relation.

Spatial relations subclasses: Local relations relate to a physical relationship established by the emerging elements (in a design sense, not in a construction sense). Local relations are characterised by notions of proximity such as: far, connected, lined up, how they fit together or separate. Examples of images expressing local relations information can be images of square living units and blocks which refer to how they are, or can be, connected. Global relations relate to the resulting configuration of spaces or items that arise from the finalised groupings of local relations. Global relations express spatial information about items, units, or components that are the cumulative result of connected elements which depicted a configuration. Examples are symbolic imagery generated by programs such as Minecraft (www.minecraft.com) to communicate the final organisation of blocks which abstractly express spatial relations between all involved local relations.

¹⁸ **Functional relations:** “In the domain of architectural design abstract relations typically corresponds to ‘functional relations’, in which forms and functions are the governing themes in the domain of functional relations” (Suwa & Tversky 1997) and whilst “conceptually distinct, are intertwined” (Suwa & Tversky 1997). The domain of functional relations denotes interactions among spaces, things, places and people visiting, using, and living within them and/or the environment. Unlike properties and spatial relations, functional relations are inherently non-visual aspects of architectural design (Suwa & Tversky, 1997).

Functional relations subclasses: This subclass is concerned with how people can interact with and use the spaces, items, and structures. In the domain of subclasses, there are four classes for functional relations: Practical roles, activity, abstract features and views. Practical roles are generally concerned

¹⁸ Refer to Table 4.6.

with concepts such as how living space should or could be. Examples include the adaptive reuse of disused car parks and office spaces. Practical roles also extend to site-related information and transportable units. Images used to reinforce the importance of certain activities, such as hygiene, sleeping and living are coded as activity. Abstract features are concerned with heat sources, health and the effects of insulation. Views, is concerned with how a final design outcome might look using visual images such as renders and other media.

Background knowledge: Cognitive science indicates that tasks undertaken by humans are mediated by background knowledge (Suwa & Tversky 1997). As the current research intends to investigate the generation of meaning in a web-based collective context, the major category of background knowledge might be understood in the context of Surowiecki's (2004) distributed crowd-based diversity. In this study it is beyond practical to suggest assessing the scope of background knowledge available from a crowd, but it is possible to document and categorise background knowledge as it is introduced. For this reason the domain of background knowledge is retained for this study. Background knowledge is intended to reflect the introduction of information that draws from personal knowledge. Images used to reflect background knowledge range from immediately recognisable objects such as existing buildings to less recognisable images that convey an abstract idea. Immediately recognisable or not, images used to convey Background knowledge communicate any information relevant to the design activity.

¹⁹ **Background knowledge subclasses:** The identified subclass of background knowledge is divided into five subclasses. Each subclass includes domain knowledge about structures, self-evaluation standards and relevance to social contexts. The five subclasses are: domain knowledge, metaphor, text, light and reflection. Domain Knowledge describes examples of existing structures and materials combined to perform specific function. Metaphor describes images used to abstractly describe technical information, ideas or social contexts. Text

¹⁹ Refer to Table 4.6.

describes any image that either refers to, is a link to, or a direct representation of a body of text. Light describes the interaction with light, and reflection describes images that are constructed to represent patterns of thought directly, and these can include abstract diagrammatic representations of thoughts and analysis.

Technical: It is highly likely that the individual within the crowd, and the crowd as a whole might exhibit novice designer characteristics in that they may not systematically approach the design task. Instead, it is likely that the individual in the crowd might reason backwards and deductively and offer general final ideas and construction ideas early on (Ericson, 1997; Zeitz, 1997). Therefore it is reasonable to conclude in advance that a crowd might exhibit similar global characteristics. To anticipate and accommodate the expected addition of any technical ideas or information that might arise early on, as the result of backward and deductive reasoning, we have extended Suwa and Tversky's (1997) existing four categories to include a new category—technical. This category is concerned with images that denote, or are related to, the expression of information concerning the final outcome, engineering of components, construction or parts, as well as methods used in constructing the outcome of the design process.

Technical subclasses: In this study, the new informational domain of technical is divided between three identified subclasses: construction method, component, and diagram. Construction method denotes images related to how structures can be put together. Component describes elements and items used in construction of a structure. A building component might be a large prefabricated element such as a shipping container and building items are individual elements such as footings and connectors. Diagrams are the physical and digitally generated drawings used to explain technical aspects of construction ideas and methods.

4.5.4 Summary of the coding scheme

Drawing on the opportunity to coordinate semiotic qualities as individual values, and design-related representational content as individual values, the developed method of coding the combined values provides quantified, semiotic qualities alongside quantified, design-informational values of imagery. Table 4.7 provides an example of how the tabularised coded semiotic values are further augmented with the design information categories outlined by Suwa and Tversky (1997) to produce the finalised organisation of the coding fields used for this study. Table 4.7 provides a tabularised overview containing examples of: a) how we code the images transition from the general to design (Sg → Sd⁽¹⁾) contextual shift; and, b) how we code the images transition from the design to design contextual shift (Sd⁽¹⁾→Sd⁽²⁾).

Table 4.7 Example of the finalised semiotic a coding scheme.

Sg					Sd ⁽¹⁾						Sd ⁽²⁾					
Circle	Img	I	In	Sy	Tr	MajCat	Subcl	I	In	Sy	Tr	MajCat	Subcl	I	In	Sy
		X			1-3	Properties	Things			X	3-3	Functional relations	Practical roles			X
			X		2-1	Properties	Things		X		2-3	Technical	Component			X
		X			1-2	Properties	Spaces		X		2-1	Functional relations	Activity		X	
			X		2-1	Properties	Things		X		2-3	Properties	Features			X

The method of coding presented in this chapter will provide the statistical data to support a general review, and a detailed analysis aimed at revealing any similarities and differences. Furthermore, the data will allow for the identification of patterns in meaning generation based on the behaviour around the construction of design meaning. With metrics, a common ground is established supporting a comparative evaluation in regards to how images aid the expression of design meaning, and flow, within the established Prezi design environment. With semiotic and design information coding schemes, there are implications that the potential ambiguity associated in subjective representational interpretation can be mitigated, to a degree, through the greater issue of categorisation and contextualisation. Lastly, with established metrics, it becomes possible to allude to the greater issue of how

representations are used by experts and non-experts when tasked with generating and communicating design meaning within an open web-based design system. Having determined the experiment setting and developed the coding scheme, the next section will discuss the main experiment (Section 4.6).

4.6 EXPERIMENT

As illustrated in Chapter 1, this study aims to research how the crowd, in the absence of design specific linguistic conventions, communicates design meaning. Our particular focus is on how the crowd will use representations to generate meaning. This outcome is achieved by comparing how two groups, an expert and a crowd, generate meaning whilst undertaking a design in an online design space (Prezi). The data collected from the expert group of designers will help to establish: (a) a set of professional design-related norms in relation to how representations are used in the generation of design meaning; and, (b) provide baseline design data from which a later comparative analysis can be drawn against the crowd group which also undertakes the same design concurrently, though separately, in the same online environment.

4.6.1 Experiment design

Selection of subjects: In this study, the selection of subjects was important, as it would influence the objectivity and reliability of the final comparative analysis. The selection criteria for the expert group and the crowd group are discussed respectively in more detail in the following sections.

The Expert group: Throughout design literature it has been noted that ten years is the estimated gestation period for the full the peak of professional maturity to be attained (Bloom, 1985; Cross, 2004; Hayes, 1981; Simon et al., 1973). The selection criterion for the four participant architects was based upon each having had more than five years architectural design experience. As the designers would work in a shared online environment there would be a cumulative baseline in shared knowledge spanning well over 20 years; a figure considered sufficient in the area of study concerning the differences between experts and novices. As a result of the extensive amount of cumulative industry

experience, a small group of experienced expert designers will undertake the design task by leveraging design heuristics commonly associated with experienced professional designers. The principle behind the use of an expert group was to reduce as much as possible individual differences and other subjective influences, and to have a group whose members were all conversant in a design language using industry-wide conventions. The activity of the expert group will: (a) provide expert-related norms regarding design related activity with the selected ODE; (b) establish the expert activity in regards to the use of the representation; and, (c) provide the baseline data from which a comparative analysis can be conducted. Four candidates comprised the expert group in our study after the recruitment process (see Appendix II for Expert Flyer).

The Crowd group: As identified, it is difficult to approach the top-down method of numerically defining crowd other than to describe it as a larger than normal gathering of a diverse range of individuals people. Similarly, it is difficult to quantify the variables involved in defining the diversity of a crowd. In generating a crowd for our study we adopted a bottom-up approach. The initial recruitment process aimed to raise awareness of our experiment using Internet forums, a dedicated Facebook page (Figure 29a) and the dedicated web page, cross-campus advertising on digital media and a dedicated word missing (Figure 29b).

The simulated crowd group size in our study was 18 candidates, after the recruitment process. The principle behind this approach was to maximise the potential for recruiting the widest array of individuals with sufficiently differing capabilities and influences commonly associated with crowd-based diversity. After raising awareness of our study, there was sufficient interest from over 40 potential Internet-based participants (see: Appendix III for Crowd Flyer). After the recruitment process concluded there was an attrition rate of 22 participants leaving 18 willing crowd participants.

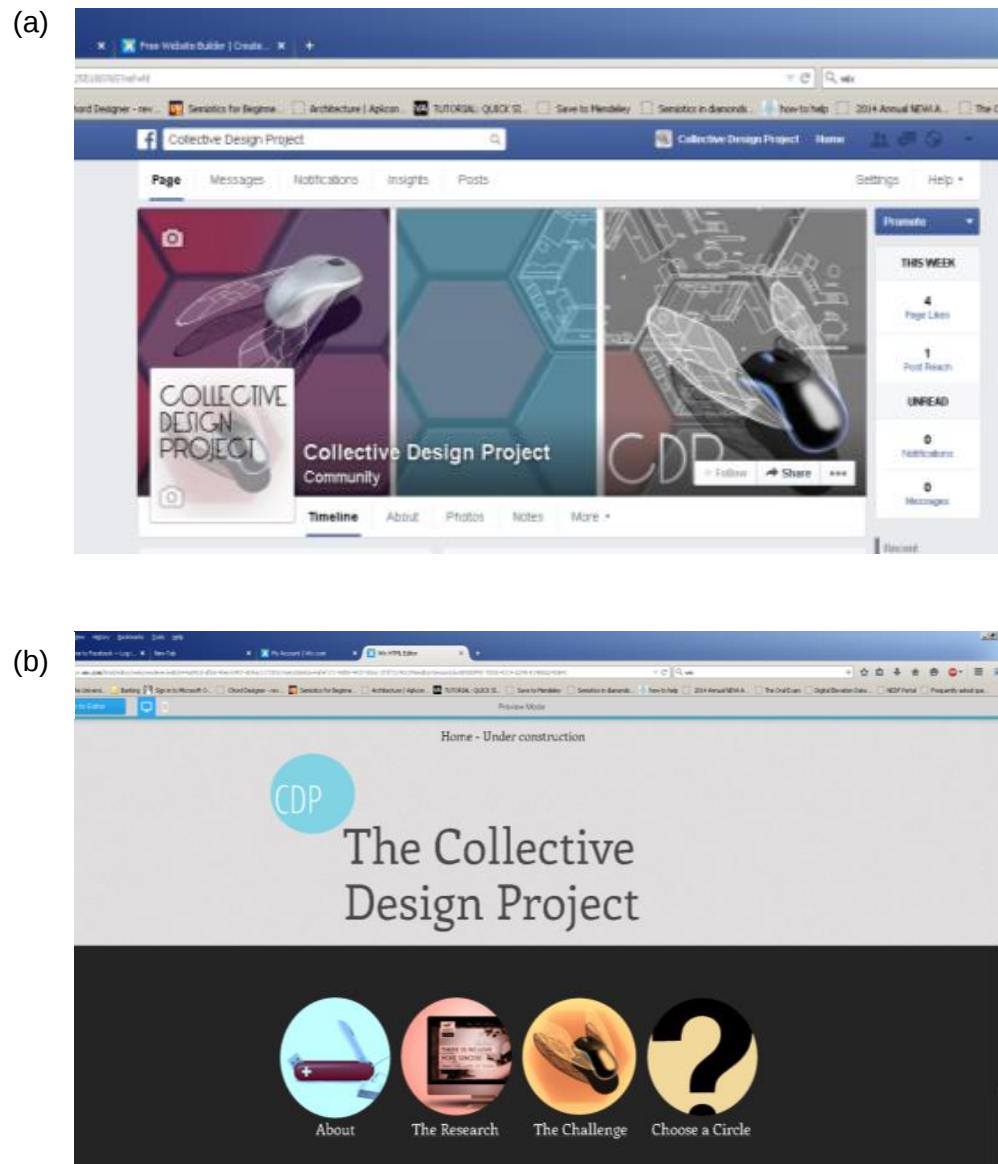


Figure 29 (a) Collective Design Project on Facebook and (b) The CDP website.

²⁰ Image source: Images generated by author are screen captures of the Facebook page and web page.

Having established the necessary parameters that are conducive to design in a collective context the study should be sufficient to provide sound results as an academic research. Because of the quality and depth of information recorded and analysed, one could not generalise from these results to comment on a much larger crowd or a larger practice-based group of expert designers. However, based on the two sample data sets, the main design behavioural patterns can be observed, identified and compared, to provide an adequate understanding of crowd-based representational use, within the given timeframe of doctoral research.

Design brief: For the purpose of this experiment it was necessary to determine what type of brief would be appropriate. In the pilot study, activity was initiated within Prezi by asking the participants to generate ideas, in any way they wished, regarding the design of an off-road, four-wheel drive camper van. The pilot study engaged four active volunteer participants using a task which simulated a design brief, in order to stimulate design-related activity. However, for a main experiment involving design experts, the task as set in the pilot study was deemed too simplistic and would need to be developed in order to stimulate activity in an expert group, as well as in a crowd group. As the crowd was expected to not have the same understanding as the expert group, a brief was required that would be simple enough for the crowd to understand yet complex enough to engage the experts, while stimulating the generation of meaningful data from both groups. If the design task were too simple, the advantages of using the experts in our ODE for baseline data may be limited. Conversely, if the design task were too complex, using a crowd may return data that could also be difficult to express. Our pilot study indicated that fewer instructions were more effective in engaging the volunteers in design activity in Prezi. Studies of online crowds have shown that the crowd is more inclined to engage with an activity when the goal was of a shared common interest (Levy, 1997).

The preliminary choice for a design task is a modular housing scheme, underpinned by globally recognised concept, commonly shared and understood by both groups—the environmental and affordability issue. The requirements set by the brief give ample room for manoeuvre in relation to determining the complexity of the design task. The combination of functions, materials and issues of a modular design exercise was flexible. Participants would need to consider the function, context, cost scale and materials. Lastly, the modular design project was a suitable setting for a wide range of variations on a theme, and for making changes. The choice of design brief was aimed at being open, allowing enough freedom to engage in the design process whereby both groups had ample room to explore the design issue, without requiring any detailed layout or drafting (See Appendix I). By using a conceptual, non-outcome based approach, we aimed to maximise the amount of representational data that could be captured and analysed.

The participants in both groups were allowed a two-week period in which to engage with the design task. For this experiment, the Prezi design space was available to access permanently. Because the data, once inserted, remained in situ, it was determined that two weeks was sufficient to allow for various types of design activity to occur.

4.6.2 Experiment procedure

To access the experiment, participants were instructed to navigate the WWW to the Prezi home screen. All participants were advised to establish a Prezi account to participate in the study. Once the users had registered an account and logged into Prezi, they were presented with a screen in which they selected the shared design space (Figure 30). As there was only one space for each group, the participants could only select the design space they had been provided access to. As such, the crowd members only accessed the crowd's design space and the experts only accessed the experts' design space. Neither group could view the other group's design space. Once the participants had joined, they were presented with a brief set of instructions. These instructions detailed how to create a personal circle within the shared Prezi space which

Please do not change THEMES or anything within this box

To begin interacting with this Prezi please double click the blue 'Edit Prezi' button.

Visit us at:
<https://TheCDProject.net>

Instructions...

Step #1

1 Select add items from the design space, choose circle and place a large circle somewhere in the space provided. This will be your design space.

2 You will use any number of items from the image and need to show where your work will be in the design space. You can add as many as you like to your design space. Please do not use any of the other participants' design space. You will use the mouse wheel to zoom in and out of your design space. (See example #1)

Example #1

Zoom in / Zoom out to see (mousewheel)

Step #2

3 After a few days in a week, we will meet again. This step simply requires participants to review everything they have done and see how it can be used in the work that others have contributed to their work for a project and perhaps for their class. And then to engage, connect, discuss, create a simple network that example #2.

Example #2

Your combined ideas

THE DESIGN CHALLENGE

We need a crowd to create and provide ideas, images and thoughts which contribute to the design of a contemporary home based on important issues facing the housing industry today - affordability and the environment.

We are looking for expressions of ideas that are daring, livable and contemporary while remaining affordable and green.

1) We want you to think about the home using a 'kit of parts' approach (modular design) where parts can later be interconnected.

2) We want you to do this in the 'Greenest' so your idea can be realised with the least impact on the environment.

It is important to understand you are not expected to have all the answers - no one person knows everything - but everybody knows something.

GOOD LUCK - And most of all, enjoy!

DON'T FORGET TO SAVE YOUR WORK.

Design Space

EXAMPLE DESIGN CIRCLE

ZOOM IN AND OUT

Figure 30 Design brief, Instructions and Rules.

²¹ The Prezi design space consisted of three main elements. The design challenge (brief), instructions (how to use the space) and the global rules (rules of participation such as not interfering or deleting the work of other participants).

would contain the participants' design activity, how to use the inbuilt functions within Prezi, and provided the design brief. Lastly, within the instructions were guidelines stating that under no circumstance should another participant's contribution be deleted.

Ethics approval: The study was granted independent ethics approval by the Human Research Ethics Committee at The University of Newcastle on January 25, 2013 (Human Research Ethics Committee [HREC]). Reference Number: H-2012-0433.

Moderation: Because we are exploring design and a crowd in an openly shared context, we identified that contingencies might need to be established in order to moderate any potentially destructive or antisocial behaviour. Should the instance arise where any destructive comments or drawings occur, they may be removed by the moderator and stored as data for later review in the analysis stage. As such, we determined that, while this study was based on openness, further to ensuring the activity followed the requirements of the participants by the researchers, any mediating role needed to be restricted to answering questions relating to issues occurring in relation to the design brief or the use of the ODE.

One stipulation was that the participants in the professional group were not allowed to participate in the project undertaken by the crowd, and participants of the crowd would not participate in the experts' session. This was easily managed by the Prezi invite system. This allowed us to send invitations for the crowd experiment to the crowd participants on their shared space and similarly for the experts and their shared space. Neither of the design spaces were visible to the other group. As such, the results from the professional group provide the control results by which we could compare the actions of our participating crowd. During the experiment, all participants were permitted to ask questions which helped them to better understand the project description and/or any other aspect of the competition and experiment.

4.6.3 Data collection

By adapting the qualities of Prezi for use as a temporary ODE, it was possible to design the experiment in such a manner that the design-related activity could be captured on a participant by participant basis. Once a participant had contributed imagery or text, the data remained in situ for the duration of the experiment. The ODE was only accessible and visible to the experiment's participants and, upon completion of the experiment; all access to the Prezi site was restricted. This was achieved by changing the access privileges to a private only setting within Prezi, allowing for unrestricted coding and analysis by the researchers. Over the course of two weeks, the cumulative result of the collected imagery and textual notations provided, together with the observational notes, the sum total of our collected data was subsequently used for three main purposes:

1. The development of a semiotic and design information coding scheme suitable for handling the flow of design meaning, as carried by imagery within the collective context provided by the adapted Prezi web space.
2. An initial general, quantitative, comparative analysis (using normalised data) to identify and isolate key issues.
3. A second detailed comparative analysis of both groups, using normalised data to explore in greater detail the isolated issues as recognised in the general analysis.

To supplement the inbuilt capacity of Prezi for capturing the design activity, daily observations were taken at two points during the day; at 9 a.m. and at 9 p.m. The notes from these observations were compiled daily and subsequently written up as detailed notes in narrative form. The snapshot observations served to record the important events which occurred throughout the duration of the experiment. As the study ran for two weeks, the snapshot approach to collecting observational data was the most appropriate supplemental approach when combined with the permanently recorded data set as saved within Prezi.

The collected data will form a summary of the work contributed by all participants and will remain available for analysis for the duration of the study. Upon completion of the study it will be deleted from the Prezi website and stored at the University of Newcastle as per Human Research Ethics Committee (HREC) guidelines and requirements.

Using the coding scheme developed for this study the captured data is organised and presented in the following chapter (5) to provide a general analysis. From the general analysis a detailed analysis emerges across chapters 6, 7 and 8 respectively.

Chapter 5: Preliminary Quantitative Results

This chapter presents the general results of the main study, including the reliability of the coding, qualitative observations, basic data description and a statistical comparison of the data distribution. The goal of this chapter corresponds to Task 3, listed in the opening section. Section 5.3 illustrates the general qualitative observations from the experiment. The comparative data sets are presented in Sections 5.4 and 5.5 and are combined and summarised in Section 5.6. Section 5.6 presents the preliminary findings from both the qualitative observations and descriptive statistics. Section 5.7 discusses the data reduction and threshold establishment and finally Section 5.8 presents the structure of the further analysis of Chapters 6, 7 and 8 which present a statistical analysis of semiotics, meaningful information and the transitional distribution of design information, respectively.

5.1 PARTICIPANTS

Our main study involved two groups; a simulated crowd group and an expert group. Each group was required to undertake one design task in our Prezi based Online Design Environment (ODE).

After the recruitment process for the crowd group had ended, our simulated crowd group consisted of a dispersed and diverse gathering of 18 participants. The age range spanned from 23 to 75 with an average age of 40. Participants were engaged from the United Kingdom, the United States and one from Australia. The gender breakdown of the crowd's participants was 38% female and 62% male. The range of occupations was also highly diverse such as (but not limited to) factory workers, retirees, machinists, a drafter, a healthcare worker, and a pet food factory owner. Of the 18 crowd participants, only two had minimal design experience, and only one had a Bachelor of Design degree. This participant is now a warehouse worker and does not practice design. In total their combined lack of design experience and the diversity of the group's makeup was sufficient to simulate a crowd in a laboratory environment, according to Surowiecki's (2004) terms of the crowd as characterised by the

diversity of its members. In terms of sample size and outcome this research is quantitative but benchmarked using qualitative methods with a small sample size. This is very typical in design studies where small protocol sample sizes are often used to generalise particular aspects of design in certain contexts.

After the recruitment process had ended for the expert group, four highly qualified design participants agreed to take part in the main experiment. Each expert met the selection criteria and all were experienced architects with over five years experience in architectural design practice and teaching. Two of the experts have been actively practising with local Architecture offices for more than six years. One participant in the expert group was practising and undertaking doctoral study. The experience of this expert included five years in two UK based practices and three years in private practice in Australia. The fourth participant was an experienced interior designer with over five years experience and a PhD in Architecture. This participant was undertaking design research in information systems. Drawing on the experiential differences between the expert and crowd groups, the results of expert participants' design activity within Prezi could provide a baseline data set sufficient for comparative purposes with the crowd group.

5.2 RELIABILITY OF THE CODING

In order to establish reliability of the coding protocol, two rounds of segmentation and coding were conducted, separated by an interval of two weeks. Inter-rater reliability for these two coding rounds was established using the Intraclass Correlation Coefficient (ICC; absolute agreement, two-way mixed, average measures). The range of the ICC is between 0.0 and plus or minus 1.0. The ICC will be high when the variation between scores given to items by the rater is small. The ICC takes into account not only the correlation between ratings, but the difference in ratings of individuals' codes. Both coding rounds were analysed across all transitions for semiotic values, major Category values and subclass values. As shown in Table 5.1, the inter-rater reliability results (ICCs) for the different Design Meaning sections ranged from 0.67 (Semiotics)

to 0.91 (Subclass) (Table 5.1). Therefore, this reliability was considered quite high for the two coding rounds undertaken.

Table 5.1 Inter-rater reliability for Design Meaning sections for coding rounds 1 and 2.

Design Meaning section	ICC	95% Confidence Interval
Semiotics ($N=506$)	ICC(3,2) = .67	[.60, .72]
Major Category ($N=265$)	ICC(3,2) = .81	[.76, .85]
Subclass ($N=268$)	ICC(3,2) = .91	[.88, .93]

Note. ICCs were measured across the transitional scores of Sg, Sd⁽¹⁾, Sd⁽²⁾ and Sd⁽³⁾ for each Design Meaning section (i.e., Sg – contains General Semiotics; Sd⁽¹⁾, Sd⁽²⁾ and Sd⁽³⁾ contain Semiotics, Major Category and Subclass information).

Following these two coding rounds, an arbitration session was carried out to document procedures, resulting in a final protocol from the combination of the two rounds. Following this, a third round of coding was conducted two weeks later. All three coding rounds for general semiotics (Sg) and design semiotics (Sd⁽¹⁾, Sd⁽²⁾ and Sd⁽³⁾) were then analysed across transitions for all items for semiotics, major category and subclass. As shown in Table 5.2 the inter-rater reliability results (ICCs) for the different Design Meaning sections ranged from 0.80 (Semiotics) to 0.91 (Major Category). This was an improvement in reliability from the first two coding rounds and the overall reliability is considered high.

Table 5.2 Inter-rater reliability for Design Meaning sections for coding round 3.

Design Meaning section	ICC	95% Confidence Interval
Semiotics ($N=506$)	ICC(3,3) = .80	[.77, .83]
Major Category ($N=265$)	ICC(3,3) = .91	[.89, .93]
Subclass ($N=268$)	ICC(3,3) = .90	[.88, .92]

Note. ICCs were measured across transition scores for each Design Meaning section (i.e., Semiotics, Major Category and Subclass information).

The data described in the following sections provides the basis for a general qualitative comparative observation (Section 5.3) and a quantitative statistical comparison of the data distributions between the crowd and expert groups (Sections 5.4, 5.5 and 5.6).

5.3 QUALITATIVE DESCRIPTION OF REPRESENTATION USE

To obtain a comprehensive overview of how the representation was applied to communicate design meaning within the ODE during the experiment, this section presents a qualitative description of the patterns of use in which the representation was involved. The collected data is presented in the following Section 5.4.2. A small number of images were generated by the participants using computer software and are original. The reproduction of these images is exactly how they were presented during the experiment and are not available in a higher resolution format. Furthermore a large number of images were imported directly from the web by the participants without referencing. Acknowledgment of the source is provided where possible.

From the sequence of recorded activity, it was apparent both groups understood the design brief. The experiment was set to run over a two-week period, allowing sufficient time for both groups to both familiarise themselves with the environment and subsequently populate the ODE with design-related data. However, given the unpredictable nature of crowds, it was unclear as to what level of engagement, if any, would occur. The crowd's initial response to the task was to contribute a grouping of images. This grouping typically revealed an area of focus by a particular crowd member.

The rate at which images were inserted was steady in the crowd. For the expert group, activity fluctuated between the first seven days with little to no activity after day seven, until day 13. After day seven of the experiment, the amount of visual information that had been provided by the participants was sufficient to catalyse a number of interactions in the crowd group (Figure 31). This was contrary to the expert group who, despite contributing a number of images (Figure 32), did not interact with any other participants' images at all until day 13 and this was further limited to a small number of interactions.

The crowd was more active in directly interacting with the representational content provided by other participants. However, the experts' interaction with

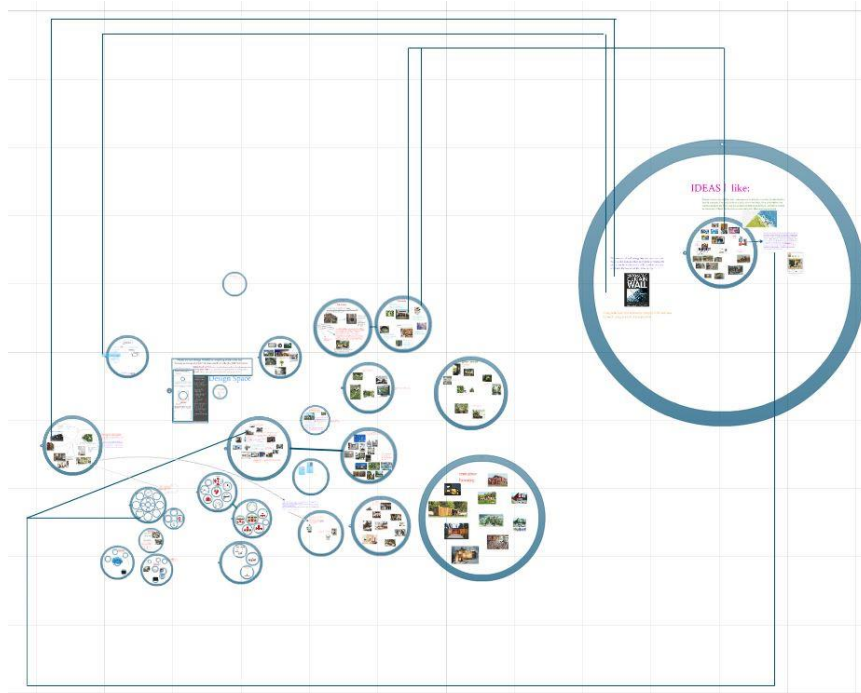


Figure 31 The crowd design space at day 14.

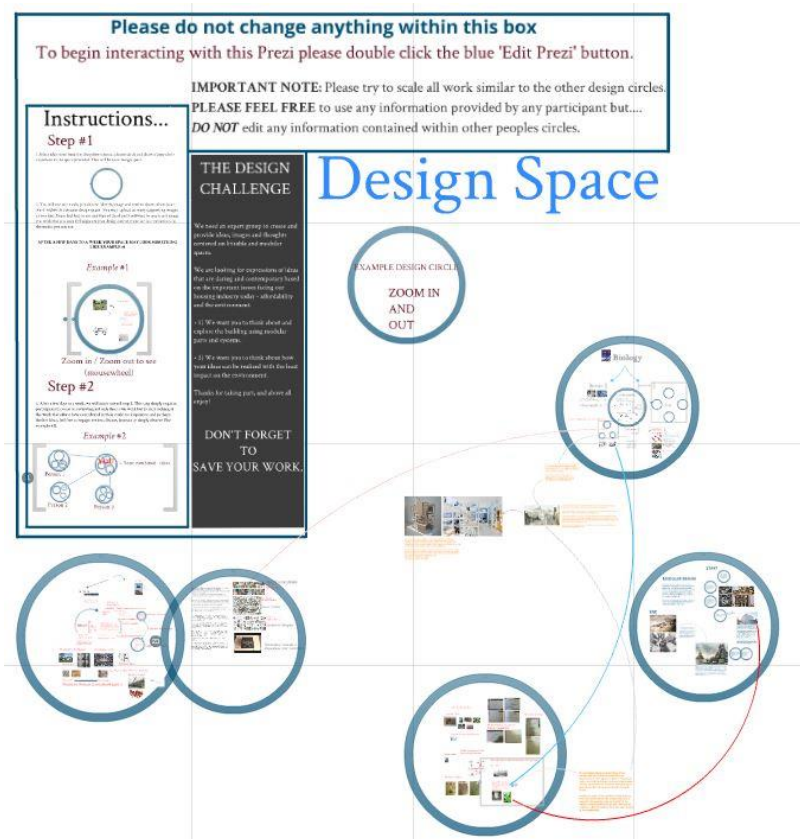


Figure 32 The expert design space at day 14.

imagery involved incorporating elements of existing imagery into their own scope of analytical work. For the crowd and the experts alike, the interactive responses were realised as observable interactions with the image, and not directly with other participants. Each interaction involved a form of modification, adapting, borrowing or copying the existing qualities of another participant's image for the purpose of conveying a newly generated meaning, in addition to the originally intended meaning.

A significant point of interest was that the participants in the crowd would draw together a collection of externally sourced, and previously unconnected, images into a circle, with the intention of communicating information in relation to a specific design issue. Through depictions of familiar items, images were intuitively and imaginatively combined to navigate and portray certain individual components of the design issue. The product of this action was that each circle contained a *schema* of information. In the crowd, this typical pattern of activity resulted in many circles, each one addressing a different area of the design issue. The range of information portrayed by each circle covered areas such as environmental factors, technical considerations (such as construction) and schematic constructs (such as drawings, plans and elevations). Figure 33 provides a typical example of a construction themed circle observed within the crowd ODE. In the expert group, certain qualities in the icon were selected for emphasising or complimenting specific lines of thought in a wider analytical exploration of the design issue (Figure 34). In contrast to the crowd's accumulation of informational parts, the role of the representation in the expert setting served a more analytical role in supporting a decomposition of the design issue. The result of this was that the representation was depended on less for its visual qualities in preference for its ability to abstractly support elements within a greater analytical exploration of the design issue. By decomposing the design problem, and using iconic representations to infer analytical components, a much higher level of abstract indexical meaning was presented in the imagery.

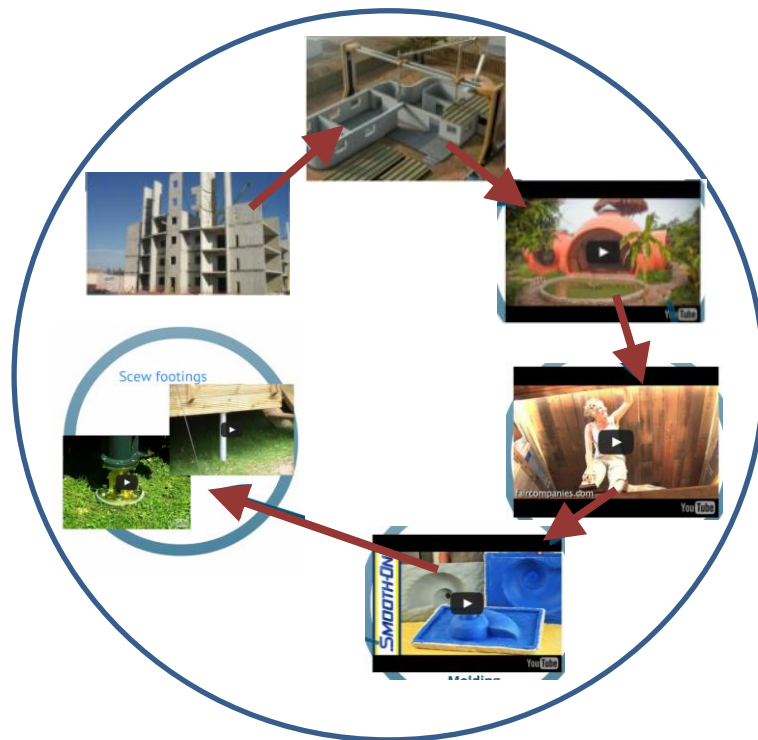


Figure 33 Construction method themed circle (by crowd participant B).

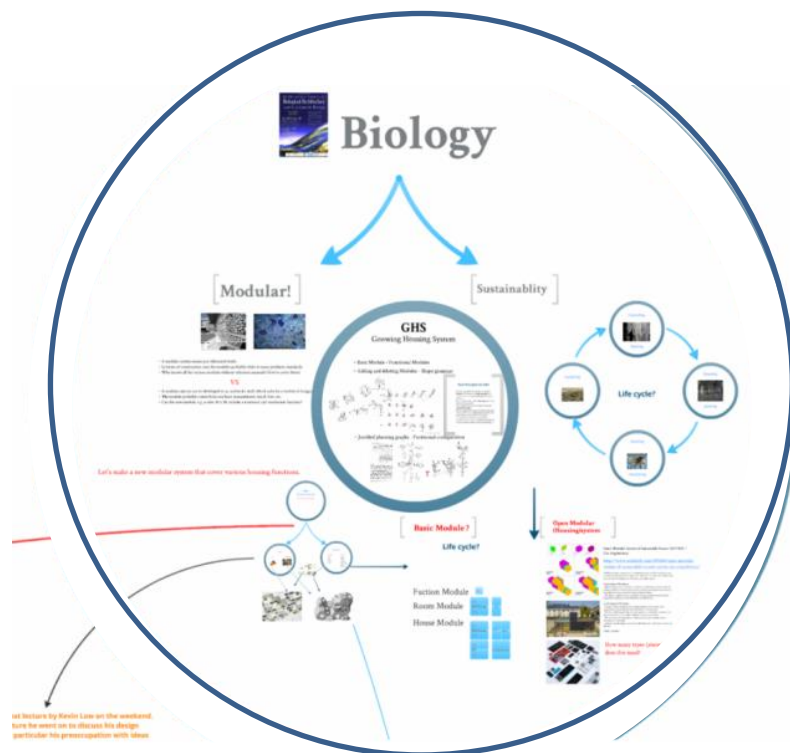


Figure 34 An expert circle showing varied imagery.

Both groups' most commonly used digital formats were either *.gif (Graphics Interchange Format) or *.jpeg (Joint Photographic Experts Group) or *.png (Portable Network Graphic) files, sourced from the Internet, or were self-generated. For both groups, all formats of digital imagery were imported from external sources. Both groups imported iconic imagery that was either scanned (such as book pages), or personally created symbolic drawings by using a variety of traditional and digital media (such as scanned hand sketches or digital Adobe Illustrator drawings). Overall the most commonly used were images collected and imported from the Internet. Despite both groups having used similar image types, there were significantly observable differences in the way both groups used the representation to elucidate the meaning in their design contribution. For example Figure 36 presents an image of a refurbished shipping container uploaded by a crowd member. The intention was to express a component suitable for modularity; furthermore, the image contained information regarding how such a unit could be furnished. In contrast Figure 35 is an example of an image used by an expert. The black and white image of exposed concrete steps was used with the main intention of conveying an abstracted consideration based on the receptive qualities of interconnected modular components and construction methods.

Despite the difference in levels of abstraction and patterns of use, a commonly shared practice in both groups was the use of the image. Both groups borrowed from existing qualities within the image to generate an analogy for the purpose of creating new meaning in relation to something other than what was directly represented in the image itself. Peirce (CP 5.171) referred to this borrowing of existing characteristics to describe non-existent things or ideas, as abduction; a reasoning process allowing for the visual description of something that does not exist, such as in design. In both groups, the use of the representation was the one commonly shared act in which both groups would engage, in order to communicate design meaning within the ODE.



Figure 35 Crowd exploring stacking configurations.

²² Image source: <http://bestofhouse.net/houses-made-from-shipping-containers/>



Figure 36 Experts exploration of repetition and connectivity.

²³ Image source: <http://www.newyorker.com/magazine/2013/01/28/slumlord>

5.4 COMPARISON OF SEMIOTIC DISTRIBUTIONS

The descriptive statistics presented in this section provide an overview of the data as captured by the coding scheme developed in Chapter 4. Section 5.4.1 provides a descriptive overview of the representations and their semiotic classifications. Section 5.4.2 provides examples of the responses to particular images which are described as interactions, and their semiotic distribution. Section 5.4.3 describes the data relating to the semiotic transitions that occur. Finally Section 5.4.4 presents the distribution of major and subclass design related information categories.

5.4.1 Semiotic starting value distributions (Sg).

The crowd group uploaded 232 general images from external sources and the expert group uploaded 81 images. In the crowd group, six images of the original 232 images were copied, and subsequently re-used within a new circle by one participant; therefore, the total final image count was 238 images (232 with six duplicates). The expert group did not reuse any images and so their total contribution remained at 81 (see Table 5.3). The number of images uploaded was proportionately different between both groups, with the experts using an average of 6.5 more images per participant than the average crowd member who used 13.7 images per participant (Table 5.3).

Table 5.3 Contributions average by group.

	Participants	Images	Average per participant
Expert	4	81	20.2
Crowd	18	232	13.7
		Diff	6.5

Of the 232 images initially introduced by the crowd, 188 were icons and 44 were symbols. No indexical images were provided. Of the 81 images introduced by the expert group, 46 were iconic, one was indexical, and 34 were symbolic (Table 5.4).

Table 5.4 Distribution of semiotics types as introduced

Sg – Starting point	Crowd		Expert	
	<i>Numeric</i>	<i>Normalised</i>	<i>Numeric</i>	<i>Normalised</i>
Icon	187	81%	46	57%
Index	0	0%	1	1%
Symbol	45	19%	34	42%
	232	100%	81	100%

To review the role of the representation in our study, it was necessary to capture the activity involving the representation from the moment it was introduced from an external source into the ODE. The imported images were first coded according to their ‘as is’ semiotic value (described in Section 5.4.1). Each image was assessed and coded using its original, non-design related semiotic value. This was achieved by applying Peirce’s semiotic triad (CP 1.369) to identify the leading semiotic characteristics of the icon, the index, or the symbol. This was undertaken for all images used by both groups for the purpose of providing an original general semiotic (Sg) context. The general semiotic context (Sg) provided a starting point from which it was possible to observe and code any subsequent modifications in the semiotic quality beyond the original (Sg) quality. Section 5.4.2 presents the comparative descriptive statistics for the captured representational activity that occurred based on selected images.

5.4.2 Captured representational activity.

The first interaction recorded in both groups, as outlined in Section 5.4.1, was the image from its original semiotic context (Sg). Once native to the ODE, the image assumes a new design-related context. The new design context is defined as ‘semiotics’ in a design context (*abbrev* to $Sd^{(n)}$). In design, the nature of interactions with representations is typically a recursive activity; however, in a little moderated collective context the number of interactions potentially might be either nil or, given time, infinite. As our experiment was limited to two weeks, the maximum amount of times an image was interacted with was recorded as five in the expert group, and four in the crowd. This was

accounted for by five different contexts (including the Sg starting point). They are: Sg (Starting point), $Sd^{(1)}$ (Design context 1), $Sd^{(2)}$ (Design context 2), $Sd^{(3)}$ (Design context 3), and $Sd^{(4)}$ (Design context 4).

Once introduced into the ODE, each image remained in place. For organisational purposes it was necessary to differentiate between the images that were involved in activity, and those that were not. All interactions were recorded as either Initial (Images drafted from external sources), Null (image without interaction), or Valid (image with interaction). From the initial 232 images supplied by the crowd at Sg, there were 27 separate valid interactions in which 27 images were used to generate further meaning (27 images went from $Sd^{(1)} \rightarrow Sd^{(2)}$). From the initial 81 images provided by the experts at Sg, there were five separate valid interactions in which five images were used to generate further meaning (five images went from $Sd^{(1)} \rightarrow Sd^{(2)}$). From $Sd^{(2)} \rightarrow Sd^{(3)}$ there were a further three valid interactions in the crowd (three images went from $Sd^{(2)} \rightarrow Sd^{(3)}$) and two valid interactions in the expert group (two images went from $Sd^{(2)} \rightarrow Sd^{(3)}$). From $Sd^{(3)} \rightarrow Sd^{(4)}$ there were no valid interactions in the crowd and one further valid interaction in the expert group (one image went from $Sd^{(3)} \rightarrow Sd^{(4)}$) (Table 5.5).

Table 5.5 Numeric distribution of interactions.

Grp	$Sg \rightarrow Sd^{(1)}$			$Sd^{(1)} \rightarrow Sd^{(2)}$			$Sd^{(2)} \rightarrow Sd^{(3)}$			$Sd^{(3)} \rightarrow Sd^{(4)}$		
CROWD	232	100%	Initial Interactions	27	12%	Valid Interactions	3	1%	Valid Interactions	0	0%	Valid Interactions
TOTAL	0	0%	Null Interactions	205	88%	Null Interactions	229	99%	Null Interactions	236	100%	Null Interactions
EXPERT	81	100%	Initial Interactions	5	6%	Valid Interactions	2	2%	Valid Interactions	1	1%	Valid Interaction
TOTAL	0	0%	Null Interactions	76	94%	Null Interactions	79	98%	Null Interactions	80	99%	Null Interactions

By coding each interaction occurring as a result of, and based around, any given representation on a point to point basis (Sg through to $Sd^{(4)}$), this study manages to quantify the changing semiotic values of the image on a per use basis within a collective design context. Section 5.4.3 provides descriptive comparative statistics for the semiotic qualities of the transitional activity that arose in both groups in the ODE.

5.4.3 Coded semiotic transitions.

Since the number of transitions and images used by both groups occurred at random intervals across the two-week open design session, the distribution of the semiotic values at each transition is presented as a numeric in Table 5.6, and then as normalised data in Table 5.7. All changes in semiotic value of the selected image, as a result of the interaction, were coded according to its change 'from' value to its 'to' value. These changes of value are identified as transition(s). In total there is a potential combination of 42 'from' and 'to' values (e.g. Icon to Index, or Index to Index). For organisational purposes the 42 combinations were divided into six categories and numbered 1 to 6 (Type 1 to 6) and each Type of transition contained 7 of the potential combinations of 'from' and 'to' value. Of the 42 potential combinations of semiotic transition that could have occurred, only 16 types of combinations were observed and coded. As the number of transitions varied in both groups and occurred at random intervals during the two-week design session, the distribution of the remaining 16 transitional combinations that did occur is presented as normalised data of both groups in Table 5.6.

The initial use of imagery in the crowd group was heavily based on importing the icon and symbol. In total, the crowd introduced 232 representations (81% icons and 19% symbols with 0% indexes) over 14 days. Of these, 27 were initially interacted with, followed by another three interactions based on the same imagery. The initial use of imagery in the expert group was heavily based on importing the icon, or symbol. In total the expert group introduced 57% icons and 42% symbols with 1% indexes over 14 days. Of these, five were initially then interacted with, followed by another two interactions, with one final interaction based on the same imagery.

Table 5.6 Numeric semiotic distributions between both groups.

Transition		CROWD				EXPERT			
		Sg → Sd1	Sd1 → Sd2	Sd2 → Sd3	Sd3 → Sd4	Sg → Sd1	Sd1 → Sd2	Sd2 → Sd3	Sd3 → Sd4
		232	27	3	-	81	5	2	1
Type 1	No.1 - Icon → Icon	31	-	-	-	1	1	-	-
	No.2 - Icon → Index	150	1	-	-	33	-	-	-
	No.3 - Icon → Symbol	1	-	-	-	7	-	-	-
	No.4 - Icon → Icon + Index	2	-	-	-	3	-	-	-
	No.5 - Icon → Icon + Symbol	1	-	-	-	-	-	-	-
	No.6 - Icon → Index + Symbol	1	-	-	-	-	-	-	-
	No.7 - Icon → Icon + Index + Symbol	1	-	-	-	-	-	-	-
	Total for <i>Icon</i> based activity	187	2	-	-	44	1	-	-
Type 2	No.1 - Index → Index	-	15	2	-	-	-	-	-
	No.2 - Index → Icon	-	3	-	-	-	-	-	-
	No.3 - Index → Symbol	-	-	-	-	-	-	1	-
	No.6 - Index → Index + Symbol	-	-	1	-	2	-	-	-
	Total for <i>Index</i> based activity	-	17	3	-	2	-	1	-
Type 3	No.1 - Symbol → Symbol	45	3	-	-	33	2	-	-
	No.3 - Symbol → Index	-	4	-	-	1	1	1	1
	No.6 - Symbol → Index + Symbol	-	-	-	-	1	-	-	-
	Total for <i>Symbol</i> based activity	45	7	-	-	35	3	1	1
Type 5	No.2 - Index + Symbol → Index	-	1	-	-	-	1	-	-
	Total for <i>Index + Symbol</i> based activity	-	1	-	-	-	1	-	-
TOTAL		232	27	3	-	81	5	2	1

Table 5.7 Normalised semiotic distributions between both groups.

Transition		CROWD				EXPERT			
		Sg → Sd1	Sd1 → Sd2	Sd2 → Sd3	Sd3 → Sd4	Sg → Sd1	Sd1 → Sd2	Sd2 → Sd3	Sd3 → Sd4
		232	27	3	-	81	5	2	1
Type 1	No.1 - Icon → Icon	13.36	-	-	-	1.23	-	-	-
	No.2 - Icon → Index	64.66	3.70	-	-	40.74	20.00	-	-
	No.3 - Icon → Symbol	0.43	-	-	-	8.64	-	-	-
	No.4 - Icon → Icon + Index	0.86	-	-	-	3.70	-	-	-
	No.5 - Icon → Icon + Symbol	0.43	-	-	-	-	-	-	-
	No.6 - Icon → Index + Symbol	0.43	-	-	-	-	-	-	-
	No.7 - Icon → Icon + Index + Symbol	0.43	-	-	-	-	-	-	-
	% Total for Icon based activity	80.60	3.70	-	0.0	54.32	20.00	-	-
Type 2	No.1 - Index → Index	-	55.56	66.67	-	-	-	-	-
	No.2 - Index → Icon	-	11.11	-	-	-	-	-	-
	No.3 - Index → Symbol	-	-	-	-	-	-	50.00	-
	No.6 - Index → Index + Symbol	-	-	33.33	-	2.47	-	-	-
	% Total for Index based activity	0.0	66.67	100	0.0	2.47	0.0	50.00	-
Type 3	No.1 - Symbol → Symbol	19.40	11.11	-	-	40.74	40.00	-	-
	No.3 - Symbol → Index	-	14.82	-	-	1.23	20.00	50.00	100.00
	No.6 - Symbol → Index + Symbol	-	-	-	-	1.23	-	-	-
	% Total for Symbol based activity	19.40	25.93	-	-	43.21	60.00	50.00	100
Type 5	No.2 - Index + Symbol → Index	-	3.70	-	-	-	20.00	-	-
	% Total for Index + Symbol based activity	-	3.70	-	-	-	20.00	-	-
TOTAL %		100%	100%	100%	100%	100%	100%	100%	100%

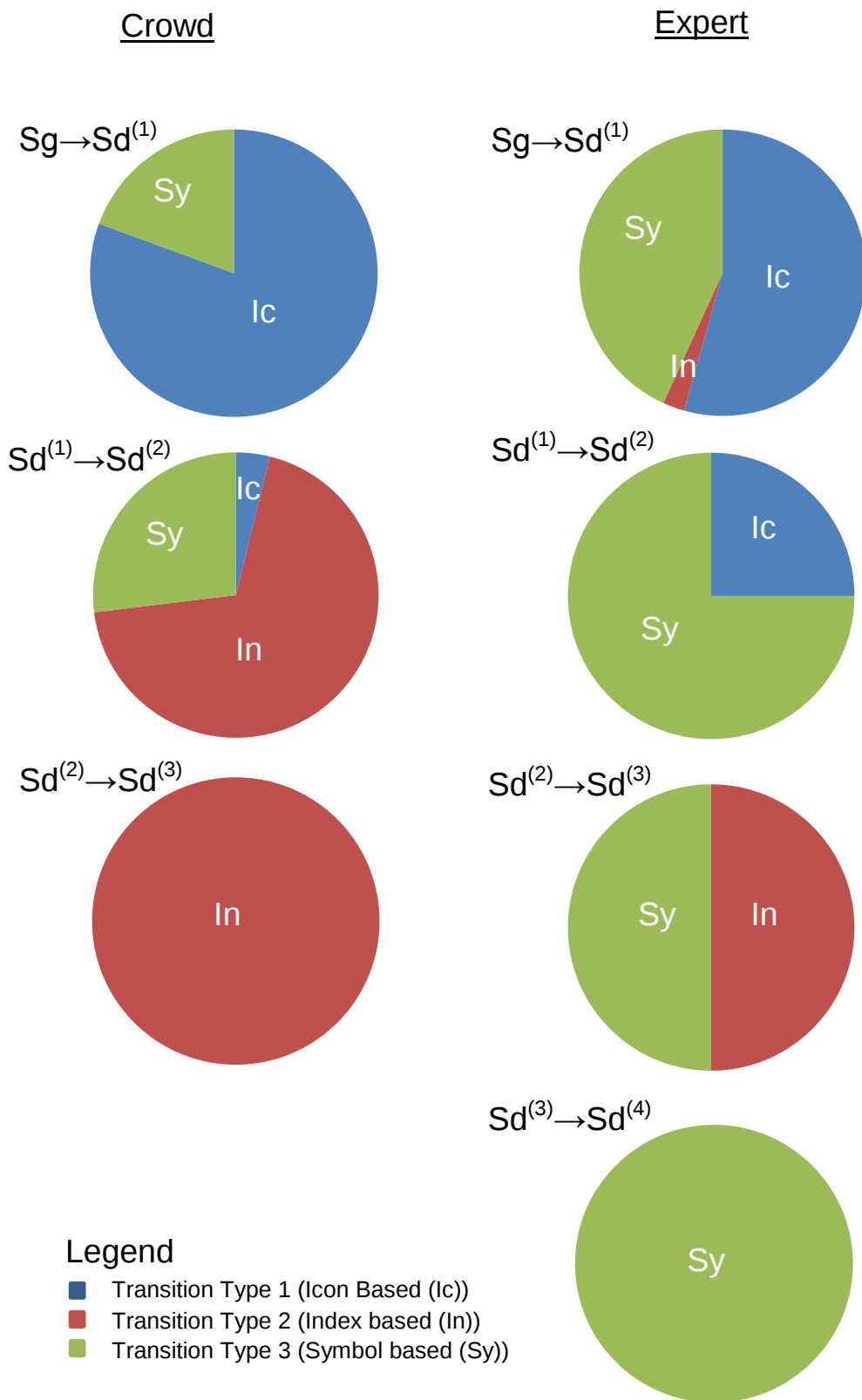


Figure 37 Pie chart visualisation of the tabularised transitional data of Table 5.7

The captured movement of semiotic changes in value (S_g through to $S_d^{(4)}$) in both groups are relevant because they infer a movement of meaning within the ODE. Typical transition examples include:

Type 1 No.1 ($S_{g(\text{icon})} \rightarrow S_d^{(1)}(\text{icon})$): Figure 38 illustrates an image taken from an external source (S_g). The image directly represents (denotes) an elevation view of three connected rectangular living units with a pool at the front. The house is well detailed and accompanied by the caption 'Container housing'. The representation is coded based on its leading semiotic characteristic; an Icon. With no subsequent interaction (Null) the originally iconic representation has received no additional meaning, and as such retains its leading (S_g) semiotic characteristic; an icon. In the context of this study this transition (from $S_g \rightarrow S_d^{(1)}$) is coded as: Transition Type 1 (No.1) and is also a typical example of many Null interactions. As such, representations such as this retain their original semiotic status until other participants used them during the course of the experiment.

Figure 38 Example transition Icon to Icon (Transition = Type 1 No.1).

Type⁽¹⁾ No.1 = $S_{g(\text{icon})} S_d^{(1)}(\text{icon})$ (<i>icon based</i>)				
Functions by	S_g - Icon		$S_d^{(1)}$ - Icon	
	PHOTO		PHOTO	
Denotes/Connotes	Denotes: Container Housing		Denotes: Container Housing	

Type 1 - No.2 ($S_{g(\text{Icon})} \rightarrow S_d^{(1)}(\text{Index})$): Figure 39 shows an image taken from an external source (S_g). The image directly represents (denotes) a very large pile of vehicle tyres. It is coded according to its leading semiotic characteristic which is iconic. Once contextualised in relation to design ($S_d^{(1)}$) the original iconic nature is still retained; however, the meaning is further complemented by the added connotation that the tyre is a viable building material. Further to this, there is another secondary connotation of recycling. As such, the originally iconic representation of tyres has now has been used to express a number of additional meanings. In this study this is coded as: Transition Type 1 (No.2)

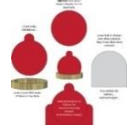
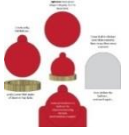
and is a typical example of how many representations were employed throughout the experiment by both groups to generate a range of indexically connected meanings based on the introduced icon.

Figure 39 Example transition Icon to Index (Transition = Type 1 – No.2).

Type⁽¹⁾ No.2 = Sg_(icon) → Sd⁽¹⁾_(index) (<i>index based</i>)				
Functions by	Sg - Icon		Sd⁽¹⁾ - Index	
	PHOTO		PHOTO	
Denotes/Connotes	Denotes: Pile of Tyres		Conn: The tyre as building material and recycling	

Type 3 – No.1 (Sg_(symbol) → Sd⁽¹⁾_(symbol)): Figure 40 shows an externally generated symbolic diagram (Sg). At Sd⁽¹⁾ the image is still immediately symbolic in nature. The diagram represents (connotes) a set of steps for the construction of a straw bale or mud-based unit that relies on using a balloon as the ‘formwork’ over which concrete can be poured, then later removed to reveal a structure. Accompanied by a brief description, the diagrams became a shared set of symbols within the context of the design task in the ODE. Once contextualised in relation to design (Sd⁽¹⁾) the original symbolic nature does not change. Any interactions involving symbolic drawings were, commonly, technically related comments. As such the originally symbolic representation of the construction remains symbolic even after being embedded with additional or new meaning. In this study, this is explained and coded as: Transition Type 3 (No.1) and is a typical example of how symbolic images and diagrams were employed throughout the experiment by both groups to generate a range of meanings aimed at describing abstract concepts and ideas.

Figure 40 Example transition Symbol to Symbol (Transition = Type 3 – No.1).

Type ⁽³⁾ No.1 = Sg (icon)→Sd ⁽¹⁾ (symbol) (<i>Symbol based</i>)				
Functions by	Sg - Symbol		Sd ⁽¹⁾ - Symbol	
	DIAGRAM		DIAGRAM	
Denotes/Connotes	Denotes: Construction method and Materials		Denotes: Construction method and Materials	

The following Section 5.5 provides the comparative descriptive statistics for the informational categories in association to their semiotic value. The informational and semiotic values are presented in the following section and are coded using the coding scheme developed in Chapter 4 Section 4.5.

5.5 COMPARISON OF INFORMATIONAL DISTRIBUTIONS

Both groups used a different number of images to express meaningful design content, the distributions of which are articulated as normalised and tabularised data in Sections 5.5.1 and 5.5.2. Each section provides a description of the major and subclass categories alongside their associated semiotic characteristics (as outlined in Section 4.3.3).

5.5.1 Major category distributions

Having applied the developed coding scheme that enables the identification of the static and shifting semiotic qualities, it was necessary to further clarify the intended design meaning from Sd⁽¹⁾ onwards. To determine the intended design meaning being engendered into the representation, this study adopted the first of Suwa and Tversky's (1997) two categories of design-related information (*Major categories* and *Subclass*). The major category is divided into: Properties, Spatial, Functional, Technical and Background Knowledge. All images were identified and categorised in association to their closest related major category. Table 5.8 presents the numeric descriptive statistics and Table 5.9 presents the normalised comparative descriptive statistics for how the images were used to

describe design content according to Suwa and Tversky's (1997) five main types of design-related information classes.

Table 5.8 The numeric account of the five types of major category of design information.

CROWD	Sd⁽¹⁾	Sd⁽²⁾	Sd⁽³⁾	EXPERT	Sd⁽¹⁾	Sd⁽²⁾	Sd⁽³⁾	Sd⁽⁴⁾
Properties	86	4	-	Properties	-	-	-	-
Spatial	11	-	-	Spatial	-	-	1	-
Functional	28	13	1	Functional	-	-	-	-
Technical	54	6	1	Technical	23	1	-	-
Background Knowledge	59	4	1	Background Knowledge	58	4	1	1

Table 5.9 Normalised percentages of the five types of major category design information.

CROWD	Sd⁽¹⁾	Sd⁽²⁾	Sd⁽³⁾	EXPERT	Sd⁽¹⁾	Sd⁽²⁾	Sd⁽³⁾	Sd⁽⁴⁾
Properties	44%	15%	-	Properties	-	-	-	-
Spatial	4%	-	-	Spatial	-	-	50%	-
Functional	8%	48%	33%	Functional	-	-	-	-
Technical	23%	22%	33%	Technical	28%	20%	-	-
Background Knowledge	21%	15%	33%	Background Knowledge	72%	80%	50%	100%

For the crowd at Sd⁽¹⁾, representations were taken from external sources (Sg) and used significantly to describe a wide range of design-related Properties (44%). At Sd⁽²⁾ Properties-related information shifted to (15%) and by Sd⁽³⁾ there were no new Properties-related representations. At Sd⁽¹⁾ Spatial information accounted for only a small percentage of imagery (4%), and no further interactions arose to generate Spatial information at Sd⁽²⁾ (0%) to Sd⁽³⁾ (0%). At Sd⁽¹⁾ Functional information similarly is represented as a small proportion (8%) but at Sd⁽¹⁾ through to Sd⁽³⁾ there are significant transitional shifts in the Functional category at Sd⁽²⁾ (48%) and at Sd⁽³⁾ (33%). The category with the most evenly distributed design-related representational content (across Sd⁽¹⁾→Sd⁽²⁾→Sd⁽³⁾) was the Technical category (23%, 22% and 33% respectively). Similarly Background Knowledge had an evenly distributed content across Sd⁽¹⁾→Sd⁽²⁾ and Sd⁽³⁾ (21%, 15% and 33% respectively).

For the expert at $Sd^{(1)}$ representations were also taken from external sources (Sg) and used significantly, although they were used to describe a far narrower range of design-related information. There were no images used to describe Properties (0%) across all four transitional stages. Similarly at $Sd^{(1)}$ and $Sd^{(2)}$ there were no images used to convey spatial information. Of the two interactions that occurred at $Sd^{(3)}$ one was Spatial (50%), by $Sd^{(4)}$ there were no more Spatial considerations (either introduced or generated through transitional activity). There were no images used to describe Functional qualities (0%) across all four transitional stages. The only points where images were significantly used to describe design information were at $Sd^{(1)}$, and these were Technical (28%) and Background Knowledge (72%). At $Sd^{(2)}$ these distributions remained relatively even with Technical (20%) and Background Knowledge (80%). During $Sd^{(3)} \rightarrow Sd^{(4)}$ there were no more interactions that resulted in Technical information being generated. Background Knowledge remained the only consistent feature of design related representations with one of the two interactions at $Sd^{(3)}$ (50%) and the last remaining interaction at $Sd^{(4)}$ (100%).

Tables 5.10 and 5.11 comparatively show the numeric and normalised (respectively) distribution of the representations' semiotic values within the major categories of design information of both groups.

Table 5.10. Numeric design information and its related Semiotic distribution.

	CROWD	Sd⁽¹⁾	Sd⁽²⁾	Sd⁽³⁾	EXPERT	Sd⁽¹⁾	Sd⁽²⁾	Sd⁽³⁾	Sd⁽⁴⁾
Properties	Icon	14	3	-	Icon	-	-	-	-
	Index	70	1	-	Index	-	-	-	-
	Symbol	-	-	-	Symbol	-	-	-	-
	Icon + Index	2	-	-	Icon + Index	-	-	-	-
	Index + Symbol	-	-	-	Index + Symbol	-	-	-	-
	Icon + Index + Symbol	-	-	-	Icon + Index + Symbol	-	-	-	-
Spatial	Icon	2	-	-	Icon	-	-	-	-
	Index	6	-	-	Index	-	-	-	-
	Symbol	3	-	-	Symbol	-	-	1	-
	Icon + Index	-	-	-	Icon + Index	-	-	-	-
	Index + Symbol	-	-	-	Index + Symbol	-	-	-	-
	Icon + Index + Symbol	-	-	-	Icon + Index + Symbol	-	-	-	-
Functional	Icon	5	-	-	Icon	-	-	-	-
	Index	14	13	1	Index	-	-	-	-
	Symbol	9	-	-	Symbol	-	-	-	-
	Icon + Index	-	-	-	Icon + Index	-	-	-	-
	Index + Symbol	-	-	-	Index + Symbol	-	-	-	-
	Icon + Index + Symbol	-	-	-	Icon + Index + Symbol	-	-	-	-
Technical	Icon	2	-	-	Icon	-	-	-	-
	Index	19	3	-	Index	2	-	-	-
	Symbol	33	3	-	Symbol	19	1	-	-
	Icon + Index	-	-	-	Icon + Index	-	-	-	-
	Index + Symbol	-	-	1	Index + Symbol	2	-	-	-
	Icon + Index + Symbol	-	-	-	Icon + Index + Symbol	-	-	-	-
B/know	Icon	8	-	-	Icon	1	-	-	-
	Index	44	4	1	Index	32	3	1	1
	Symbol	4	-	-	Symbol	21	2	-	-
	Icon + Index	-	-	-	Icon + Index	3	-	-	-
	Index + Symbol	2	-	-	Index + Symbol	1	-	-	-
	Icon + Index + Symbol	1	-	-	Icon + Index + Symbol	-	-	-	-
	TOTAL (Norm)	100%	100%	100%	TOTAL (Norm)	100%	100%	100%	100%
	TOTAL (Num)	238	27	3	TOTAL (Num)	81	5	2	1

Table 5.11 Normalised design information and its related Semiotic distribution.

	CROWD	Sd ⁽¹⁾	Sd ⁽²⁾	Sd ⁽³⁾	EXPERT	Sd ⁽¹⁾	Sd ⁽²⁾	Sd ⁽³⁾	Sd ⁽⁴⁾
Properties	Icon	6%	11%	-	Icon	-	-	-	-
	Index	29%	4%	-	Index	-	-	-	-
	Symbol	-	-	-	Symbol	-	-	-	-
	Icon + Index	1%	-	-	Icon + Index	-	-	-	-
	Index + Symbol	-	-	-	Index + Symbol	-	-	-	-
	Icon + Index + Symbol	-	-	-	Icon + Index + Symbol	-	-	-	-
Spatial	Icon	1%	-	-	Icon	-	-	-	-
	Index	3%	-	-	Index	-	-	-	-
	Symbol	1%	-	-	Symbol	-	-	50%	-
	Icon + Index	-	-	-	Icon + Index	-	-	-	-
	Index + Symbol	-	-	-	Index + Symbol	-	-	-	-
	Icon + Index + Symbol	-	-	-	Icon + Index + Symbol	-	-	-	-
Functional	Icon	2%	-	-	Icon	-	-	-	-
	Index	6%	48%	33%	Index	-	-	-	-
	Symbol	4%	-	-	Symbol	-	-	-	-
	Icon + Index	-	-	-	Icon + Index	-	-	-	-
	Index + Symbol	-	-	-	Index + Symbol	-	-	-	-
	Icon + Index + Symbol	-	-	-	Icon + Index + Symbol	-	-	-	-
Technical	Icon	1%	-	-	Icon	-	-	-	-
	Index	8%	11%	-	Index	2%	-	-	-
	Symbol	14%	11%	-	Symbol	23%	20%	-	-
	Icon + Index	-	-	-	Icon + Index	-	-	-	-
	Index + Symbol	-	-	33%	Index + Symbol	2%	-	-	-
	Icon + Index + Symbol	-	-	-	Icon + Index + Symbol	-	-	-	-
Back / know	Icon	3%	-	-	Icon	1%	-	-	-
	Index	18%	15%	33%	Index	40%	60%	50%	100%
	Symbol	2%	-	-	Symbol	26%	20%	-	-
	Icon + Index	-	-	-	Icon + Index	4%	-	-	-
	Index + Symbol	1%	-	-	Index + Symbol	1%	-	-	-
	Icon + Index + Symbol	-	-	-	Icon + Index + Symbol	-	-	-	-
	TOTAL (Norm)	100%	100%	100%	TOTAL (Norm)	100%	100%	100%	100%
	TOTAL (Num)	238	27	3	TOTAL (Num)	81	5	2	1

A chi-square test showed that the proportion of images assigned to the five categories (Properties, Spatial, Functional, Technical and Background Knowledge) differed significantly between the expert group and the crowd group, $\chi^2(4) = 90.3, p < .001$. Table 5.11 shows that the majority of the expert

group's images are in the Background Knowledge category (72.2%) and the Technical category (26.7%), whereas the majority of the crowd images are more widely spread across the Properties category (33.6%), the Background Knowledge category (23.9%) and the Technical category (22.8%).

5.5.2 Subclass distribution

Table 5.12 shows the detailed numeric distribution of images and Table 5.13 shows the detailed normalised distribution of images and their corresponding design-related meaning within the major categories of Properties, Spatial issues, Functional relationships, Technical information and Background Knowledge across all transitional stages.

Table 5.12 Numeric account of types of Subclass Design information.

	CROWD	Sd⁽¹⁾	Sd⁽²⁾	Sd⁽³⁾	EXPERT	Sd⁽¹⁾	Sd⁽²⁾	Sd⁽³⁾	Sd⁽⁴⁾
Properties	Spaces	19	-	-	Spaces	-	-	-	-
	Things	20	2	-	Things	-	-	-	-
	Features	29	1	-	Features	-	-	-	-
	Materials	17	1	-	Materials	-	-	-	-
Spatial	Local relations	5	-	-	Local relations	-	-	1	-
	Global relations	6	-	-	Global relations	-	-	-	-
Functional	Practical roles	2	9	1	Practical roles	-	-	-	-
	Activity	9	-	-	Activity	-	-	-	-
	Abstract features	4	4	-	Abstract features	-	-	-	-
	Views	13	-	-	Views	-	-	-	-
Technical	Construction Method	17	3	1	Construction Method	1	-	-	-
	Component	6	1	-	Component	-	-	-	-
	Diagram	32	2	-	Diagram	22	1	-	-
Background	Domain Knowledge	43	-	-	Domain Knowledge	26	3	1	1
	Metaphor	3	2	-	Metaphor	14	1	-	-
	Text	5	2	1	Text	11	-	-	-
	Light	4	-	-	Light	-	-	-	-
	Reflective	4	-	-	Reflective	7	-	-	-

Table 5.13 Normalised percentages of types of Subclass Design information.

	CROWD	Sd ⁽¹⁾	Sd ⁽²⁾	Sd ⁽³⁾	EXPERT	Sd ⁽¹⁾	Sd ⁽²⁾	Sd ⁽³⁾	Sd ⁽⁴⁾
Properties	Spaces	8.0	-	-	Spaces	-	-	-	-
	Things	8.4	7.4	-	Things	-	-	-	-
	Features	12.2	3.7	-	Features	-	-	-	-
	Materials	7.1	3.7	-	Materials	-	-	-	-
Spatial	Local relations	2.5	-	-	Local relations	-	-	50.0	-
	Global relations	2.1	-	-	Global relations	-	-	-	-
Functional	Practical roles	3.8	33.3	33.3	Practical roles	-	-	-	-
	Activity	0.8	-	-	Activity	-	-	-	-
	Abstract features	1.7	14.8	-	Abstract features	-	-	-	-
	Views	5.5	-	-	Views	-	-	-	-
Technical	Construction Method	7.1	11.1	33.3	Construction Method	1.0	-	-	-
	Component	2.5	3.7	-	Component	-	-	-	-
	Diagram	13.4	7.4	-	Diagram	27.0	20.0	-	-
Background	Domain Knowledge	18.1	-	-	Domain Knowledge	32.0	60.0	50.0	100
	Metaphor	1.3	7.4	-	Metaphor	17.0	20.0	-	-
	Text	2.1	7.4	33.3	Text	14.0	-	-	-
	Light	1.7	-	-	Light	-	-	-	-
	Reflective	1.7	-	-	Reflective	9.0	-	-	-

For the crowd, within the major categories of Properties, Spatial, Functional, Technical, and Background Knowledge, the entire subclass range of information was accounted for. The images used by the experts to support Background Knowledge (72%) fell on Domain Knowledge, Metaphor, and Text with Diagrams accounting for 27% of the images within the Technical major category. These differences in informational consideration infer that, within the ODE, the crowd group and the expert group respond to a design task by similarly using the image, but to generate different sets of information. These differences will be discussed in more detail in Chapter 6.

5.6 SUMMARY

This section presents the comparative description of the overall distribution of the semiotic values and the informational values within the ODE. Tables 5.17 and 5.19 present a numeric and normalised (respectively) articulation of the semiotic data. The tables also provide a detailed synopsis which illustrates the

semiotic distribution among the major and subclass informational categories. From the tables, it is possible to see that the image is clearly used by the crowd, not only to express meaning, but to deliver a comprehensive distribution of information. This is in contrast to the experts who use the image to express a narrower range of meaning. Table 5.14 provides a range of typical examples of the type of images that were applied by the crowd for the purpose of describing meaningful design content within the ODE. In Table 5.14 the main headings present the Major category with an example image. Underneath each image is its subclass value and its design-related semiotic value(s).

Table 5.14 Crowd major category and subclass examples and associated semiotic value.

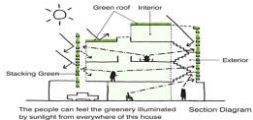
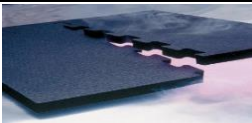
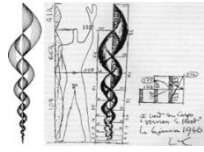
PROPERTIES		
		
Things (Icon)	Feature (Icon)	Material (Index)
SPATIAL		
		
Local Relation (Icon)	Spatial Relation (Symbol)	Global Relation (Index)
FUNCTIONAL		
		
Views (Icon)	Abstract Features (Index)	Activity (Icon)
TECHNICAL		
		
Component (Index)	Diagram (Symbol)	Construction Method (Symbol)
BACKGROUND KNOWLEDGE		
		
Domain Knowledge (Index)	Metaphor (Index+Symbol)	Light (Index)

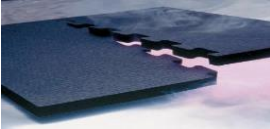
Table 5.15 shows a range of typical examples of the type of images that were applied by the experts for the purpose of describing meaningful design content within the ODE. As in Table 5.14, the main heading in each row presents the Major category with an example image. This is followed by the image with its subclass value and its design-related semiotic value(s).

Table 5.15. Experts' major category and subclass examples and associated semiotic value.

TECHNICAL		
		
Diagram (Symbol)	Diagram (Index)	Diagram (Symbol)
BACKGROUND KNOWLEDGE		
		
Domain Knowledge (Icon)	Metaphor (Symbol)	Reflective (Symbol)

In terms of the information they generate, the contribution of both groups can be accounted for by the distribution in the semiotic values and the distribution of the design information values. Table 5.16 provides a compacted visual comparative example in which it is possible review the initial differences of how imagery is employed to describe various types of Background Knowledge in both groups.

Table 5.16 Expert major category and subclass examples and associated semiotic value.

BACKGROUND KNOWLEDGE	
CROWD	EXPERT
	
Domain Knowledge (Icon)	Domain Knowledge (Icon)
CROWD	EXPERT
	
Metaphor (Index+Symbol)	Metaphor (Symbol)

There is a significant difference in the distribution of information and the abstract vs. less abstract method by which it is done. This difference in the way the representation is being used to present design information by the crowd and the experts infers that comparisons can be drawn based on the experts' vs novices' literature, as it is the crowd which contains novice participants.

Table (5.17) summarises the previously articulated numeric data in its entirety (Tables 5.6, 5.8, 5.10, and 5.12). Table 5.18 summarises the previously articulated normalised data in its entirety (Tables 5.7, 5.9, 5.11, and 5.13). By combining the data of all the tables, this section provides a comprehensive statistical summary of the coded data. By combining and presenting the data in its entirety it is possible to review the semiotic distributions and their relation to the informational categories as well as the change in semiotic and informational values (transitions) over time.

Table 5.17 Numeric distribution of semiotic values and informational content - all transitions.

		CROWD								EXPERT																						
		SD1				SD2				SD3				SD1				SD2				SD3				SD4						
Major Cat	Sub Class	Icon	Index	Symbol	Icon + Index	Index + Symbol	Icon+Index+Symbol	Icon	Index	Symbol	Icon + Index	Index + Symbol	Icon+Index+Symbol	Icon	Index	Symbol	Icon + Index	Index + Symbol	Icon+Index+Symbol	Icon	Index	Symbol	Icon + Index	Index + Symbol	Icon+Index+Symbol	Icon	Index	Symbol	Icon + Index	Index + Symbol	Icon+Index+Symbol	
		Spaces	1	17		1																										
		Things	2	18			2																									
		Features	6	22		1																										
		Materials	5	12				1																								
		Local relations	1	2	3																											
		Global relations	1	4																												
		Practical roles	1	8				9																								
		Activity	2																													
		Abstract features		4																												
TECHNICAL	Views	2	1	10																												
	Construction Method		15	2		2	1																									
BACKKNOW	Component	2	4			1																										
	Diagram	1	31				2																									
	Domain knowledge	8	35																													
	Metaphor			1	2																											
	Text		5				2																									
	Light		4																													
	Reflective			3																												
	Individual Totals	31	152	50	2	2	1	3	21	3																						
TOTAL		238					27					1				81				5				2				1				

Table 5.18 Normalised distribution of semiotic values and informational - all transitions.

		CROWD										EXPERT									
Major Cat	Sub Class	SD1					SD2					SD3					SD4				
		Icon	Index	Symbol	Icon + Index	Icon+Index+Symbol	Icon	Index	Symbol	Icon + Index	Icon+Index+Symbol	Icon	Index	Symbol	Icon + Index	Icon+Index+Symbol	Icon	Index	Symbol	Icon + Index	Icon+Index+Symbol
PROPERTIES	Spaces	3.2	11.2		50.0																
	Things	6.5	11.8				66.7														
	Features	19.4	14.5		50.0		33.3														
	Materials	16.1	7.9					4.8													
SPATIAL	Local relations	3.2	1.3	6.0																	
	Global relations	3.2	2.6																		
FUNCTIONAL	Practical roles	3.2	5.3					42.9			50.0										
	Activity	6.5																			
	Abstract features		2.6					19.0													
TECHNICAL	Views	6.5	0.7	20.0																	
	Construction Method		9.9	4.0			9.5	33.3													
	Component	6.5	2.6				4.8														
	Diagram		0.7	62.0				66.7													
BACKKNOW	Domain knowledge	25.8	23.0							50.0	100										
	Metaphor			2.0		100															
	Text		3.3																		
	Light		2.6																		
	Reflective			6.0																	
Semiotic % Dist/Per SD		13.0	63.9	21.0	0.8	0.8	0.4	11.1	77.8	11.1		66.6					80	20		50	50
TOTAL		100 % (238)					100 % (27)					100 % (3)					100% (81)				
																	100% (5)				
																	100% (2)				
																	100% (1)				

5.7 STRUCTURE OF FURTHER ANALYSIS

Based on the descriptive data presented in this chapter, the following three chapters will further analyse the summarised data outlined in Tables 5.17 and 5.18 in Section 5.6. The following three chapters combined, aim to address Objective (4) as listed in Section 1.2.2. The three parts of the analysis illustrate the semiotic and informational distribution respectively (quantitative comparative analysis), the aggregation of semiotic and informational values and their 'over time' distribution (cumulative comparative analysis), and the trend of the transitional design movement (quantitative comparative analysis).

1. *Quantitative comparative analysis*— To describe the qualitative nature of the representation and its role in carrying design-related, semiotic information; a combined comparative approach is adopted. A combined qualitative and quantitative approach is often applied when, as in this case, neither the specific use of qualitative or quantitative methods alone will provide sufficient breadth. As such, a combined approach can offset the weaknesses of either approach (if used individually) (Bazely, 2012; Driscoll, 2007).
2. *Cumulative comparative analysis*— A cumulative comparative analysis is used to calculate and compare the combined value of the aggregated semiotic and informational data. A cumulative comparative analysis is a method which measures the relative design effort of participants over a session by calculating the accumulative occurrence of a value between a low value starting point and a final accumulated total (Gero & Kannengiesser, 2014). The measurement methods in this comparative analysis are adopted from Gero and Kannengiesser's (2014) study on the cumulative analysis of multidisciplinary designers' behaviour. The measurements are based on the cumulative occurrence of the semiotic values, the informational values, and transitional values across a 14-day, permanently open, web-based design session.

The combined method is an accepted approach for transforming coded qualitative data into quantitative data. The process of transforming coded qualitative data, such as semiotic information into quantitative data is described as 'qualitising' (Bazely, 2012). Once the qualitative data has undergone qualitising into quantitative data, it is possible to undertake a more objective comparative analysis based on the presence of statistical information (Driscoll, 2007).

A combined, quantitative, comparative analysis based on quantified data is an established method enabling the researcher to identify phenomena such as subgroup characteristics or to identify patterns such as behaviours and relationships between particular variables (Andrew & Halcomb, 2009). The combined quantitative comparative analysis presented over the following three chapters, aims to reveal the details as to how the experts and the crowd generated design meaning through representations during the entire design session. Due to a lack of quantitative approaches for substantiating the qualitative nature of semiotic meaning in design, this study uses a custom-developed coding scheme which captures and quantifies semiotic values alongside design-related informational categories. The following analysis is achieved using statistical information and cumulative information drawn from the coded semiotic and informational activity of both groups. From this, the aim is to develop an understanding of the range and scale of the data. As such, a combined, quantitative, comparative analysis of the semiotic and informational values of the representations, and over time, semiotic and informational changes; will, when combined, cumulatively describe the construction and movement of design meaning by both groups in the ODE.

Table 5.19 Structure of further analysis.

Chapter	Content of analysis	Tools	Outcome
6	Presents an analysis of the combined semiotic and informational data to better understand how meaningful information is generated in both groups.	Quantitative Comparative Analysis	Addresses Hypotheses 2
7	Presents an analysis revealing that central to the generation of design knowledge in both groups, the representation facilitated different approaches in both groups to the generation of meaningful information.	Cumulative Comparative Analysis	Addresses Hypotheses 2
8	The transitional activity that produced semiotic movement and newly generated meaningful design information.	Quantitative Comparative Analysis	Addresses Hypotheses 2

5.8 DATA REDUCTION AND THRESHOLD ESTABLISHMENT

To make the following analysis more effective, it was determined that only the first three transitions presented enough data (Sg through to Sd⁽²⁾) to be reliable. From Sd⁽²⁾ through to Sd⁽⁴⁾ there was not enough data in either group to be able to reliably compare and generalise the activity. As such the data for transitions Sd⁽²⁾ through to Sd⁽⁴⁾ are omitted. Furthermore, there was a threshold imposed on any data below 5%. Data falling below this range across the transitions was merged to its nearest semiotic counterpart. For example, a transition Type 1 No.7 (Icon to Icon + Index + Symbol) was considered by its leading semiotic characteristic and merged to the icon to icon value (Table 5.20).

The remaining data considered viable for a comparative analysis was reduced to three main transitions (Sg→Sd⁽¹⁾→Sd⁽²⁾) containing seven of the potential 42 types of semiotic changes in value. The descriptive data distribution of the semiotic values from this chapter implies that there are both similarities *and* differences between the experts and the crowd. This chapter reveals that fundamentally, the icon to index transition is a shared semiotic similarity in both groups. It also reveals that the persistent presence of the symbol is a shared similarity in both groups.

Table 5.20. The reduced data with omitted types of transition that fell under 5%.

Transition		CROWD			EXPERT		
		Sg to Sd ⁽¹⁾	Sd ⁽¹⁾ to Sd ⁽²⁾	Total All	Sg to Sd ⁽¹⁾	Sd ⁽¹⁾ to Sd ⁽²⁾	Total All
		232	27	259	81	5	86
Type 1	No.1 - Icon → Icon	15.08	-	15.08	1.23	-	1.23
	No.2 - Icon → Index	65.09	-	68.79	40.74	20	60.74
	No.3 - Icon → Symbol	-	-	-	8.64	-	8.64
	% Total for <i>Icon</i> based activity	80.6	-	84.3	54.32	20	74.32
Type 2	No.1 - Index → Index	-	55.56	55.56	-	-	22.47
	No.2 - Index → Icon	-	11.11	11.11	-	-	0
	% Total for <i>Index</i> based activity	-	70.37	70.37	2.47	-	22.47
Type 3	No.1 - Symbol → Symbol	19.4	11.11	30.51	43.2	40	80.74
	No.3 - Symbol → Index	-	14.82	14.82	2.46	20	22.46
	% Total for <i>Symbol</i> based activity	19.4	25.93	45.33	43.21	60	103.21
TOTAL %		100	100	200	100	100	200

Both groups used the image to generate design-related information and both groups, in order to achieve this, depended significantly on the icon and symbol to index transition, to generate indexical information. For example, in the crowd group, 65% of the images introduced were icons and 21% were symbols. The experts' use of the icon reveals a balanced approach with introduced 40% icons to index ratio and a 42% symbol to symbol ratio. As the underlying value of the semiotic quality is impartial to expertise (or lack thereof), the semiotic values provide a good comparative starting point upon which the informational values can rest. There is a significant difference in the distribution of information between groups with the crowd group covering all informational categories and the expert group remaining focused on a much narrower range of informational categories. These similarities and differences will be explored in greater detail in Chapters 6, 7 and 8.

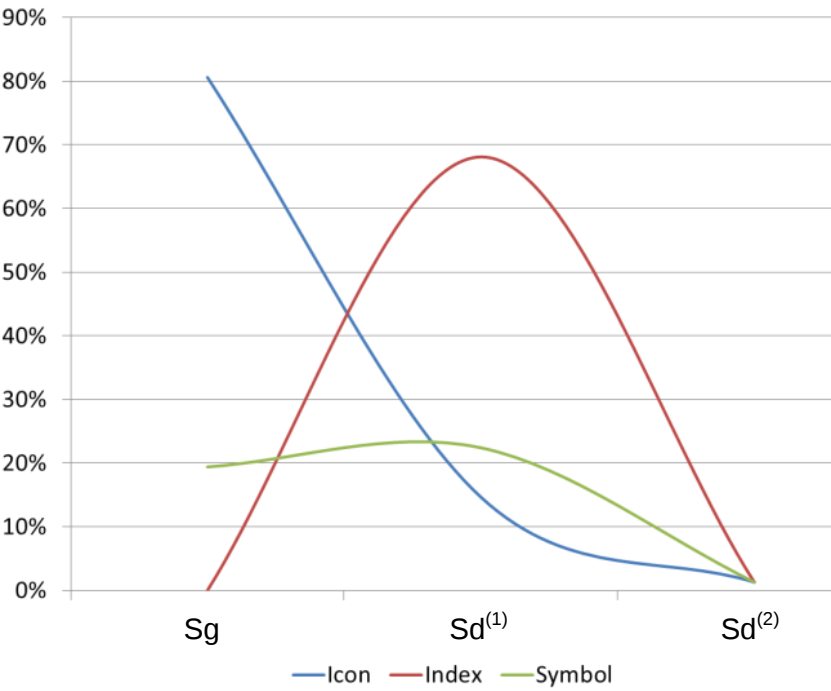
Chapter 6: Representation and its role in the ODE

To further understand how representation was used in the ODE during the 14-day design session, this chapter presents a quantitative comparative analysis based on two sets of interlinked statistical data. The goal of this chapter corresponds to Task 4, listed in the opening section. Section 6.1 provides a review and comparison of the semiotic distributions and characterises the role of the icon, index and symbol and its application toward the generation of design information. Section 6.2 compares the informational categories in association with the semiotic values. Combined, these two datasets aim to reveal if any quantitative trends, patterns or characteristics emerge from the combined statistical values between the two datasets.

6.1 SEMIOTIC DISTRIBUTION

Figure 41 presents a normalised overview of the semiotic values as they were presented over the course of the experiment. During the 14-day experiment, both the crowd and expert groups selected and imported into the ODE a proportionally similar range of digital images. The changing dynamic semiotic values appear to be a shared characteristic between the groups. In both groups the initial transition, from $S_g \rightarrow S_d^{(1)}$, is characterised by the selection and importing of the iconic imagery into the ODE (indicated by the blue line in both Crowd and Experts Figure 41). At $S_d^{(1)}$ this value drops markedly and is replaced by the increase in indexical semiotic values (indicated by the red line in Figure 41). Present at both S_g and $S_d^{(1)}$ in both groups, but smaller in range, is indicated by the green line in Figure 41.

CROWD



EXPERT

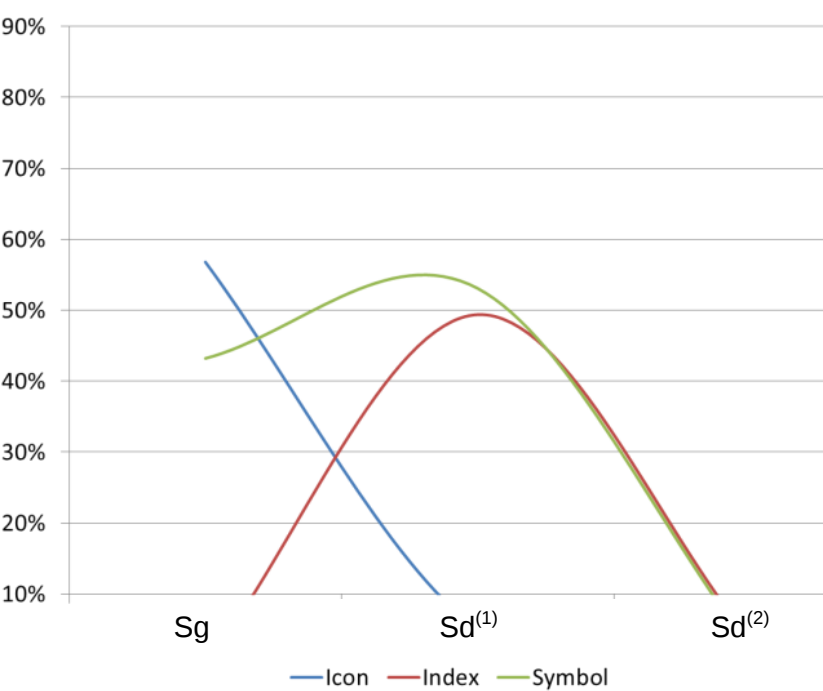


Figure 41 Logarithmic trendlines showing the Type 1 interactions.

The transitional activity captured at $Sg \rightarrow Sd^{(1)}$ might be characterised as an account of the initial introduction of the image. The presence of a high rate of iconic values at Sg indicates the crowd imported imagery for the purposes of using them in a design context. Similarly, the high rate of iconic values at Sg in the expert group suggests a similar pattern of activity to the crowd group and that the experts were also sourcing external images for use in a design context. This introduction of imagery by both groups had the effect of generating a primary or initial set of visual data which served as a documentary record of the captured individual process, and a referential resource for other members engaged with the task in the ODE. $Sg \rightarrow Sd^{(1)}$ was the first major transition, and as such, it involved a large number of images in both groups. In the crowd group beyond Sg the activity involving the iconic-related image was markedly reduced. Similarly beyond the Sg context there were no more iconic values in the expert group. For the crowd and expert group alike, the shared peak revealed at $Sd^{(1)}$ in index-related semiotic values corresponds with the sharp decrease of icon-related values.

The symbolic semiotic value is visibly present in both groups across all three transitional stages, although in proportionately different ratios. In the transitional sequence of $Sg \rightarrow Sd^{(1)}$ both groups used images that started with an iconic or symbolic value, and later this value switched to either the predominantly indexical (for the crowd), or indexical and symbolic (for the expert) value. $Sd^{(1)} \rightarrow Sd^{(2)}$ revealed interactions were taking place based on the images supplied by other participants who generated further additional semiotic values creating the $Sd^{(2)}$ context. For the crowd, $Sg \rightarrow Sd^{(1)}$ $Sd^{(2)}$ was dominated by a shift toward indexical values. In contrast, the experts' shift appeared balanced with both symbolic and indexical values in equal measure. This might suggest there was little difference in the way the image was used. Also it might indicate the presence of the collective, as well as the experts' ability to use symbolic material in the ODE to communicate abstracted design information. The movement that spanned three contextual stages might also suggest the capacity for design information to flow in a collective context. Following is a

comparative breakdown of the sequential process in regards to the icons' most prominent role at Sg, the index's role which was most prominent at Sd⁽¹⁾, and the symbol which was evident throughout all three contextual stages.

6.1.1 Icon-based activity at Sg→Sd⁽²⁾

In both groups the presence of the iconic semiotic value is largely accounted for by its external and general value. Figure 42 presents a detailed distribution of the types of semiotic shifts in value that occurred within the Sg→Sd⁽¹⁾ transition. To the left is the Type 1 No.2 (icon-to-index) transition. To the right is the Type 3 No.1 (symbol-to-symbol) transition. There were no icon-to-symbol transitions; however, the omnipresent nature of the symbol will be addressed in more detail in Section 6.2.3. It can be observed that both groups share peaks in the types of transitional activity involving the icon and the symbol. For the experts, the icon-to-index is proportionately equal to their symbol-to-symbol activity (40% and 41% respectively). Though semiotically exhibiting similar transitional characteristics, the activity in the crowd group is less evenly distributed between the types of semiotic movement. The icon-to-index accounts for 64% and symbol based activity is half that of the experts (19%).

The Sg→Sd⁽¹⁾ transition was the only transition of the three (Sg→Sd⁽²⁾) in which the icon featured prominently in any activity in both groups. According to Peirce, the icon is essential for the creative process because:

Icons are also necessary to create new ideas, since the only way to conveying new ideas is by means of a “complexus of [...] icons”. We can only create new ideas by transforming existing images. Only by means of a conjunction or a disjunction of icons can we arrive at composite images of which the whole is not [yet] familiar (CP 3.433) (as quoted by Noth, 2000).

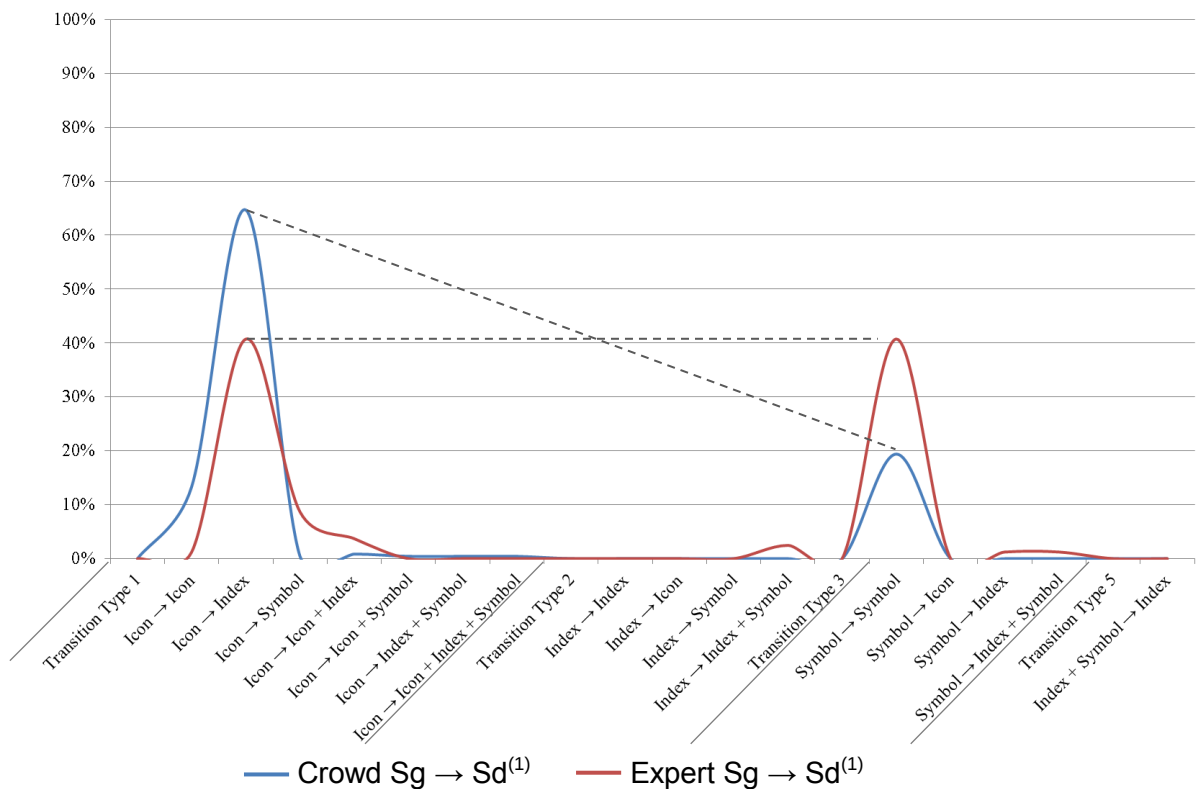


Figure 42 The normalised distribution of transitions at – $Sg \rightarrow Sd^{(1)}$.

²⁴ A logarithmic trendline can be characterised as a best-fit curved line that can be useful when the rate of change in the data increases or decreases quickly and then levels out. A logarithmic trendline can represent negative and/or positive values. Often when a zero value is represented using a logarithmic trendline the line is considered as a negative value and it appears to drop from the graph plot area when the negative value is omitted from the plot axis (Figure 41). Figure 41 and all subsequent graphs presented throughout this dissertation use the logarithmic trendline visualisation.

The proportionately high ratio of icons present in both groups in the transition from Sg to the index at Sd⁽¹⁾ suggests a similarity in both sourcing and appropriating the necessary iconic presentations for the purpose of conveying design-related meaning. In its Peircean association with the creative process, the icon is relied upon for its existing qualities. The existing iconic qualities are borrowed, and elements of that image are associated with new information; in exchanging the original iconic value for a new indexical and symbolic value(s), analogous information is conveyed based on associations created with the images of existing things. The icons' highly visible presence at Sg, and the index's presence at Sd⁽¹⁾ might suggest that the crowd and experts share a similar pattern of behaviour in that both groups naturally drew upon the properties of the icon to express a design meaning indexically, inferring that creative processes were occurring in both groups.

6.1.2 Index based activity at Sg→Sd⁽²⁾

Of the 232 images presented in the crowd ODE at Sg→Sd⁽¹⁾, 27 of these were reused to increase the informational value. Of the 81 images presented in the expert ODE at Sg→Sd⁽¹⁾, five of these were reused to increase the informational value. A chi-square test was used to determine whether there was a significant difference between the crowd and expert groups in the proportional use of images between Sd⁽¹⁾ and Sd⁽²⁾. The crowd reutilised 10.4% of the 232 images which generated the Sd⁽²⁾ context in their ODE, whereas the expert group reutilised 5.8% of their 81 images for the same purpose. This difference was not statistically significant, $\chi^2(1) = 1.63$, $p = 0.202$. In terms of design activity, this infers that, at a functional level, the image might be as equally relevant for the crowd as it is for the experts when establishing, communicating, and generating additional design-related information in the context of this study.

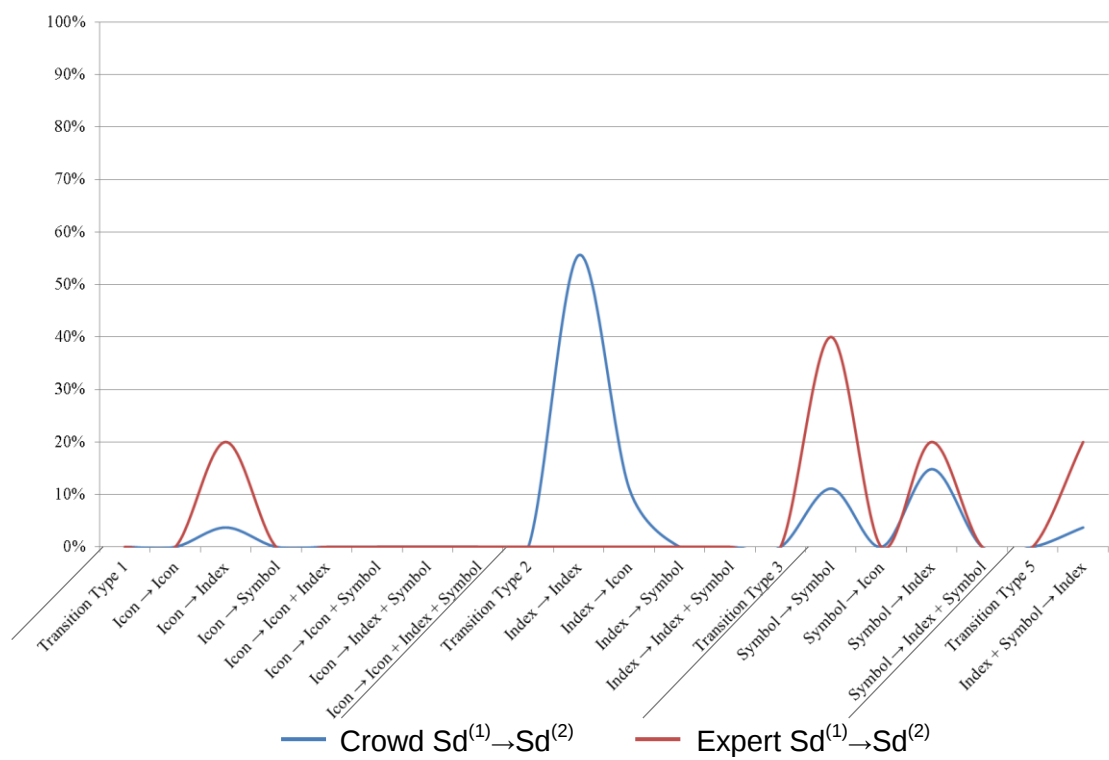


Figure 43 The normalised distribution of transitions at $Sd^{(1)} \rightarrow Sd^{(2)}$.

At $Sd^{(1)} \rightarrow Sd^{(2)}$ it is the index-to-index transition that is the defining characteristic for the crowd. The experts' data indicates the continued mixed use of index and symbolic imagery as the preferred method for communicating associative meaning. This is demonstrated by the difference in Type 2 (index based) transitional movement within the crowd group in comparison to the expert group's index-related activity (Figure 43).

Despite the dominant shift from icon Sg to index $Sd^{(1)}$ (81% icons at Sg to 68% index at $Sd^{(1)}$) in the crowd group and the shift from icon Sg to index $Sd^{(1)}$ (57% icons at Sg to 49% index at $Sd^{(1)}$) in the expert group, the results indicate the emergence of a different pattern of semiotic interaction in both groups. The crowd continued to interact with the $Sd^{(1)}$ index-related material in order to generate associative information. In contrast the balance of index/symbol-related transitions in the expert group suggests that, despite the presence of index-related information at $Sd^{(1)}$, the experts were less reliant overall on the index for associative meaning. This divergence suggests a difference in the way the representation is used in the generation of associative information. In the crowd, the presence of indexical transitions, based on existing $Sd^{(1)}$ index-related imagery within the ODE, reveals a pattern of additively making analogies based on existing $Sd^{(1)}$ imagery. The generation of extra analogous meaning using existing $Sd^{(1)}$ imagery contributed to an accumulation of shared knowledge, opening a window for the potential for further analogies to develop. In contrast, in the expert group from $Sd^{(1)} \rightarrow Sd^{(2)}$ where there was no index-related transitional activity.

The presence of the semiotic value shift from $Sd^{(1)} \rightarrow Sd^{(2)}$ is relevant because at a metalevel it provides evidence of the movement of design meaning within the collectively shared context beyond the initial contextualisation of Sg iconic imagery to describe design related information at $Sd^{(1)}$. From $Sd^{(1)} \rightarrow Sd^{(2)}$ the movement in design meaning involved five transitions in the expert group and 27 transitions in the crowd group. No transitions in semiotic value occurred as a result of direct traditional collaborative processes; instead the movement of design meaning arose as a result of interacting with images already present

within the environment. This was the same for both groups and is discussed in more detail in Chapter 8.

The results of the activity from $Sd^{(1)} \rightarrow Sd^{(2)}$ reveal a shift away from iconic information toward expressing indexical information in the crowd, in contrast to the continued symbolic representations used in the expert group. As well as the importance of the shift in semiotic value itself, this potentially indicates a diversification in the way the representation was used to convey design information. The crowd continued to rely largely on the index to generate meaning whereas the experts favoured the symbol for the same purpose. The high ratio of indexical meaning suggests a continued reliance of drawing on analogies from the qualities of existing objects within images to create and extend the existing $Sd^{(1)}$ design information. The immediate effect of the continued generation of this analogous information was the accumulation of a rich visual repository, allowing for potential further analogies to occur. In contrast, the expert group from $Sg \rightarrow Sd^{(2)}$ decreased its icon-related activity and remained consistent in the use of the symbol. The presence of the transitional activity based on the symbol remained unchanged from the $Sd^{(1)}$ transition (at 41%). According to Daehler et al. (1993), the experience in a certain domain, such as design, affects the way subjects represent knowledge. The resulting consistency in symbolic presence in the expert group suggests that, despite the design activity taking place in a web-based environment, the experts extended their practice of generating analogies using symbolic representations into this environment.

Overall, the decrease in icon-related activity, the absence of index-related activity, and the presence of symbol-based activity suggests the experts were most likely coding design knowledge using familiar symbolic methods.

Furthermore, their symbolic activity suggests the expert group might have been concentrating on what they considered the more relevant aspects of the design issue, which is consistent with design literature. The crowd, with a lower level of developed knowledge, tended to exhibit elevated index related behaviours. This occurred through either: the continued addition or saturation of imagery, or

existing images (from $Sd^{(1)}$) which were reused to extend the informational content of the participants' (who elected to borrow the qualities) knowledge base (at $Sd^{(1)} \rightarrow Sd^{(2)}$). This activity suggests that, in starting the design task the crowd was inadvertently saturating the environment allowing them to further establish relationships between problems of a particular type, and form generalisations of that type of problem (Ross & Kennedy, 1990). The activity involving the symbol is discussed in more detail in Section 6.3.3.

6.1.3 Symbol-based activity at $Sg \rightarrow Sd^{(2)}$

Figures 44 and 45 show the consistent presence of symbol-based semiotic activity arising in both groups within all three transitions ($Sg \rightarrow Sd^{(2)}$). For the crowd, the symbol was also evident across Sg , $Sd^{(1)}$, and $Sd^{(2)}$ as 19%, 22% and 11% respectively. For the experts, the symbol-related activity across transitions Sg , $Sd^{(1)}$ and $Sd^{(2)}$ was 43%, 53%, 40% respectively. The difference in values might suggest that the expert group were using symbolic information more readily than the crowd. However, the presence of symbolic meaning in both groups suggests varying levels of competence in each group with abstracted information. This is due to the symbol being naturally abstract, because the semiotic value inherent in the symbol is that it does not resemble the signifier in any shape or form. Any connection to what is being represented is purely conventional (Chandler, 2002). In a general context, a symbol operates not by using visual or conceptual connections to the signified, but through established conventions (Chandler, 2002; Chapman, 2004; Pierce, 1982). To this end, the symbols present in both groups in relation to design information must carry varying levels of abstraction.

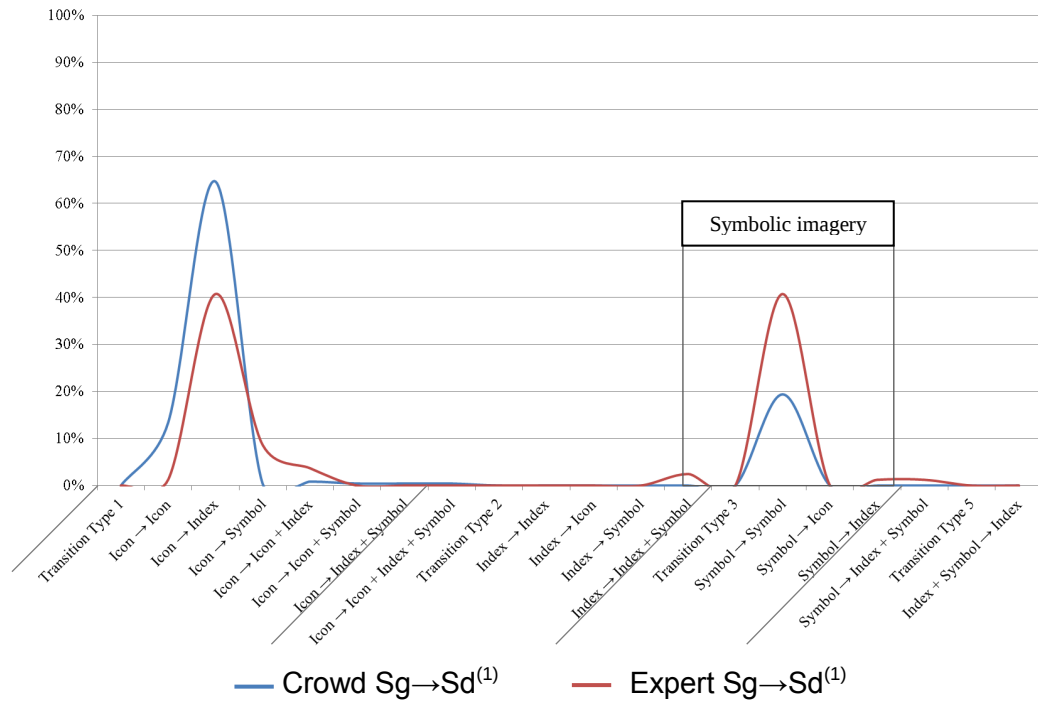


Figure 44 Trendlines of the $Sg \rightarrow Sd^{(1)}$ symbolic values.

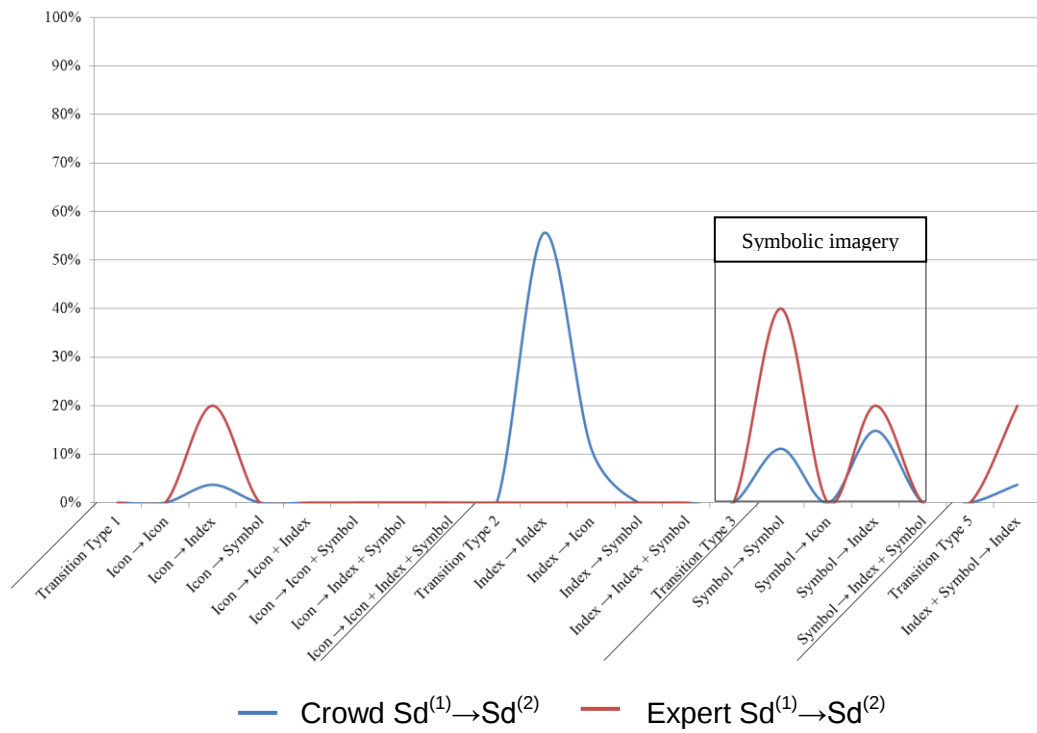


Figure 45 Trendlines of the $Sd^{(1)} \rightarrow Sd^{(2)}$ symbolic values.

The use of symbolic imagery is a particular characteristic of the expert designer as it enabled the expression of a particular type of vocabulary within the design discourse. Symbolic information often helps the professional organise the material into familiar categories and determine whether the designer has considered all the information he usually considers (Wade, 1977). Professions such as design have, over time, developed highly formalised notational systems to handle the communication of various types of information from the start of the task, where the notations are necessarily vague and abstract to explain conceptual exploratory and abstract ideas (Göel, 1995), to the final stages where the notational systems used are more concrete and defined (plans, sections, and elevations). The symbol at each stage of the design development will carry a meaning that corresponds with each stage of the design progress. The higher presence of the symbolic image in the ODE suggests that in a web-based collective context, this type of expert behaviour in expressing design meaning is not impacted. The presence of the symbol in the crowd group infers that within the ODE, the crowd also exhibits a pictorial competence similar to experts when selecting symbolic imagery to communicate abstract information.

6.2 COMPARISON OF INFORMATIONAL VALUES

6.2.1 Comparison between information ranges at $Sd^{(1)}$

Figure 46 illustrates the comparison of the quantified occurrence of images used to describe information belonging to one of the five categories of design information in the ODE at $Sd^{(1)}$. While Figure 46 shows the major category measurements, Figure 47 shows the related subclass measurements and their distribution within the major category classes at $Sd^{(1)}$. From Figures 46 and 47, we can infer that, from the 232 transitions that occurred in the crowd groups and the 81 transitions that occurred in the expert group, there was a significant amount of information introduced (Sg) by using the image to generate the first design context $Sd^{(1)}$.

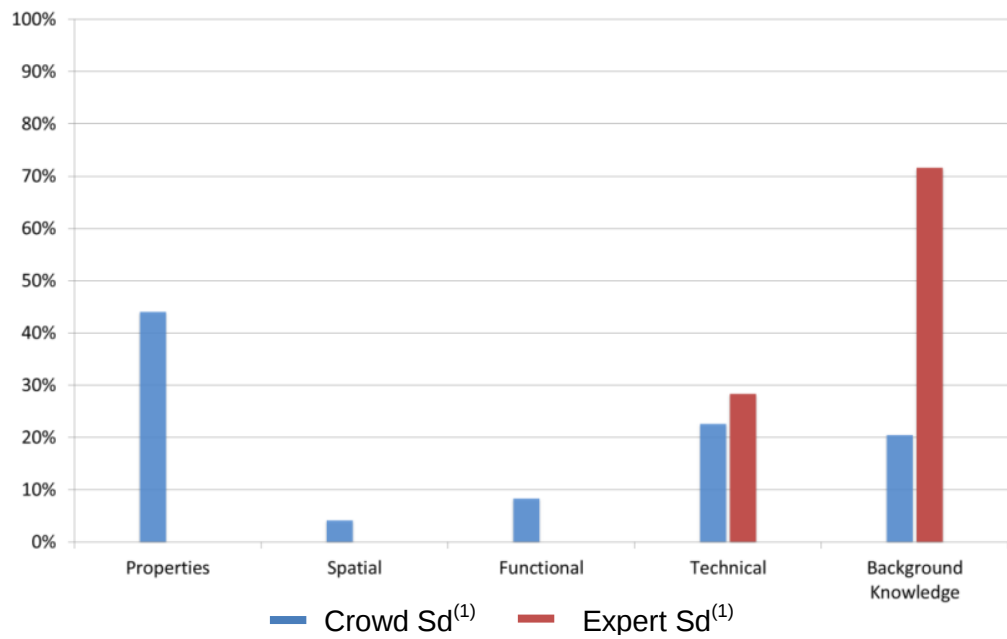


Figure 46 Normalised distribution of Major categories across Sd⁽¹⁾.

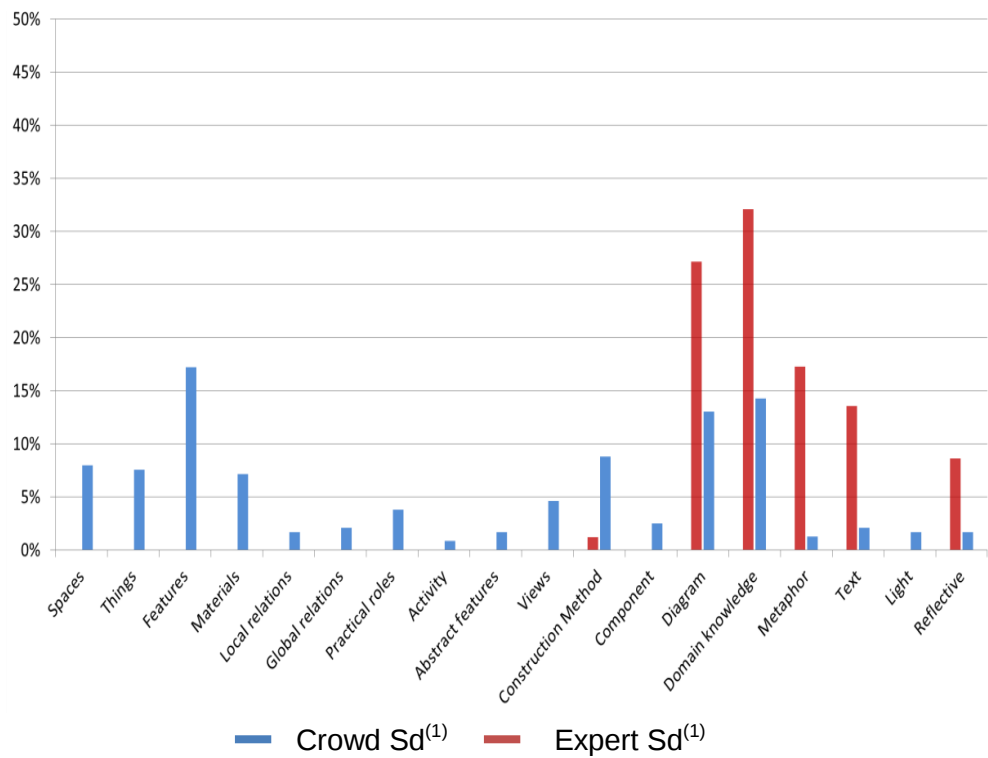


Figure 47 Normalised distribution of Subclass categories across Sd⁽¹⁾.

From the $Sg \rightarrow Sd^{(1)}$ transition it is possible to identify two characteristics: firstly, in the context of the ODE, both groups similarly employed representational imagery in support of the generation of design information. The effect of this characteristic activity revealed a second characteristic: the range of information with which the image was used to generate at $Sd^{(1)}$ differed in both groups in terms of the scope and intended informational content. The distribution of images to information shows that, at the beginning of the design session in the ODE ($Sg \rightarrow Sd^{(1)}$), the image was introduced and used to convey a diverse range of design information in the crowd. Using a proportionately similar number of images; however, the range of informational categories was narrower in the expert group. At both crowd and expert levels, the image was extensively employed at $Sd^{(1)}$ for the purpose of generating a primary body of design information. Yet despite this shared characteristic, the distribution of image to information categories at $Sd^{(1)}$ could suggest differences in approach in the use of the image in terms of its intended content.

6.2.2 Comparison between information ranges at $Sd^{(2)}$

Figure 48 illustrates the comparison of the quantified occurrence of images used to describe information belonging to one of the five categories of design information in the ODE at $Sd^{(2)}$. While Figure 48 shows the major category measurements, Figure 49 shows the related subclass measurements and their distribution within the major category classes at $Sd^{(2)}$.

At both crowd and expert levels, the distribution of image to informational content at $Sd^{(2)}$ remained relatively fixed within the same informational distribution as its $Sd^{(1)}$ distribution. At $Sd^{(2)}$ the crowd continue to remain diverse in their informational consideration and the experts continue to remain focused on a smaller range of informational categories. The consistency of both groups and their relative informational distribution at $Sd^{(1)}$ and $Sd^{(2)}$ shows a minimal deviation in the ranges of informational content. Even with the addition of information to existing images via the transition itself, the range of information in both groups remains relatively fixed in the crowd's diversity versus the experts' concentration.

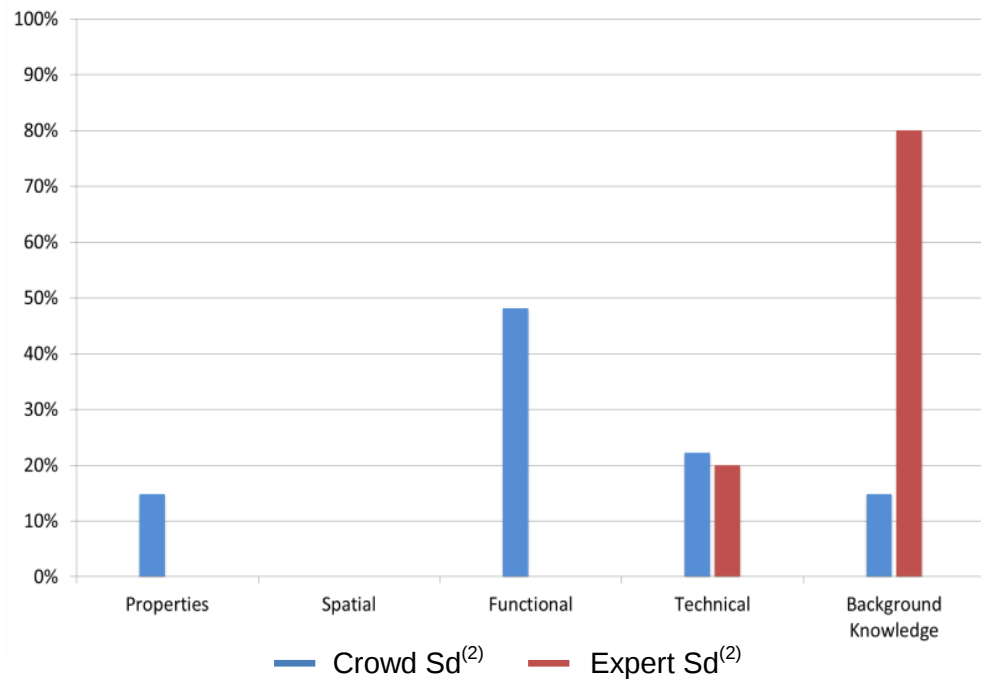


Figure 48 Normalised distribution of Major categories across $S_d^{(2)}$.

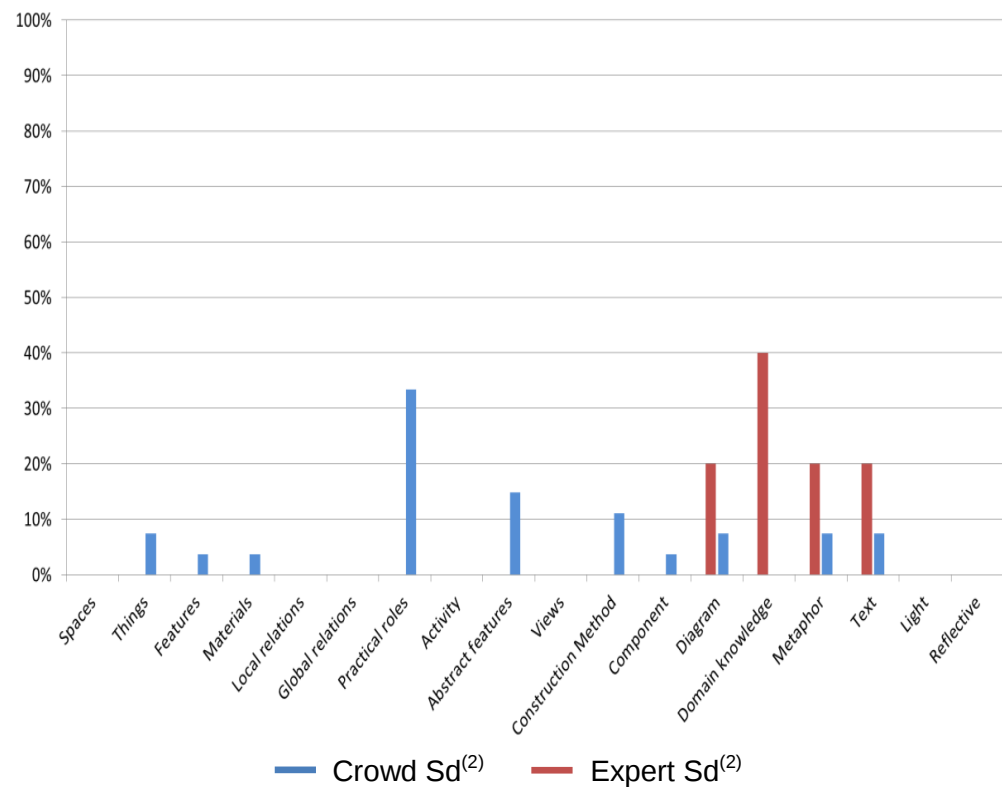


Figure 49 Normalised distribution of Subclass categories across $S_d^{(2)}$.

6.2.3 Combined crowd semiotic informational characteristics

Figure 50 illustrates, with a dark blue line, the semiotic distribution of $Sd^{(1)}$ images used by the crowd to describe information belonging to two of the five categories of design information in the ODE. The lighter blue line denotes the semiotic distribution of images to information at $Sd^{(2)}$. Across categories at both $Sd^{(1)}$ and $Sd^{(2)}$ it is the index which is the dominant characteristic with the symbol present, but much less dominant. From Figure 51, the diverse semiotic distribution across the informational areas (characterised by mostly indexical imagery) shows that the crowd group exercised a comparatively different set of design-related heuristics in approaching the task.

The semiotic qualities of Sg , $Sd^{(1)}$ and $Sd^{(2)}$ suggest that the crowd group engaged with the design problem by using the icon for analogous purposes to present content, similarly to the experts who used the indexical and symbolic to present content. This information is unequally dispersed across all informational categories. Both groups similarly used the icon ($Sg \rightarrow Sd^{(1)}$) to initially present precedents. In terms of semiotic distribution, there was little difference in semiotic activity at this stage. At $Sd^{(1)}$ and $Sd^{(2)}$, the once Sg iconic information became referential and both groups similarly exhibited index and symbol-based patterns of activity. The Sg icon to $Sd^{(1)}$ index to $Sd^{(2)}$ index and symbol in both groups reveals the informational areas in which the crowd used imagery to express analogous associative processes within the ODE.

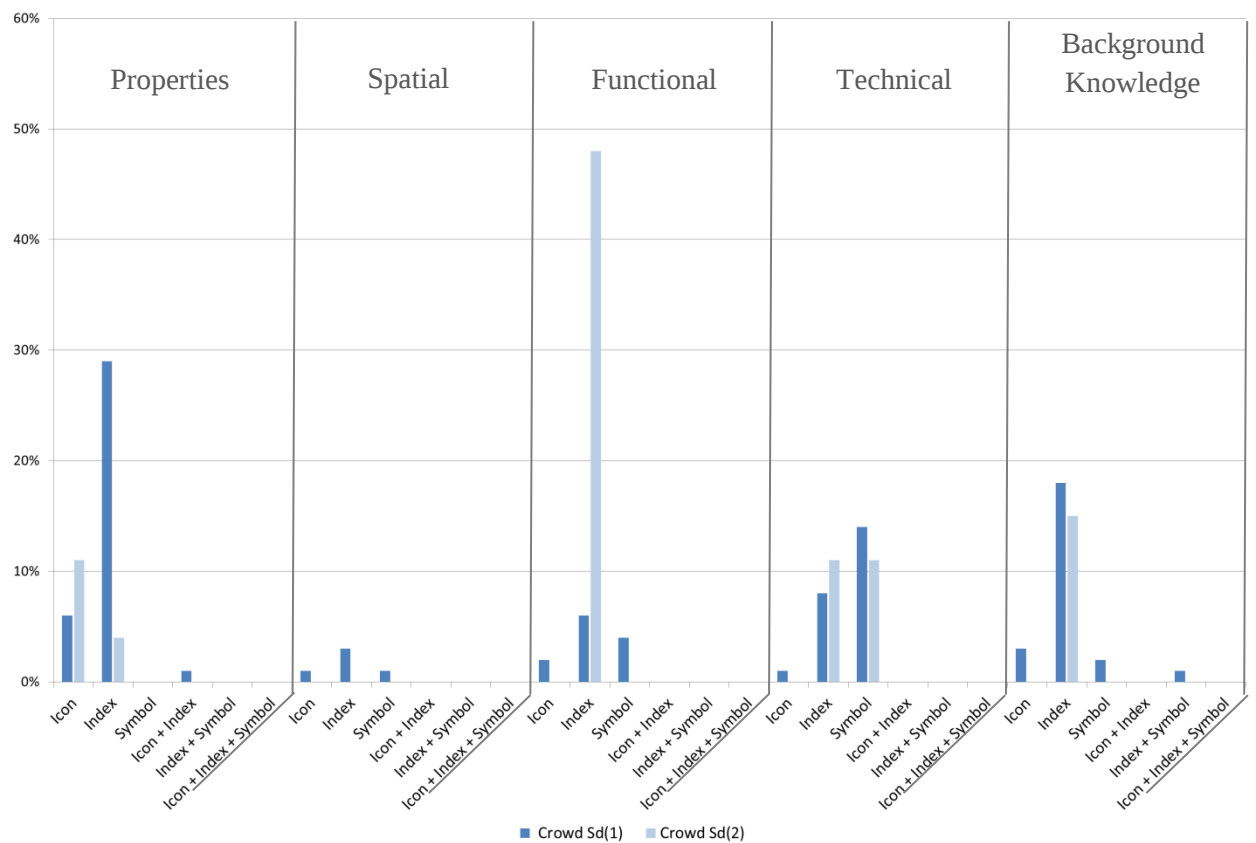


Figure 50 Normalised spread of crowd subclass categories across $Sd^{(1)}$ and $Sd^{(2)}$.

6.2.4 Combined expert semiotic informational characteristics

Figure 51 illustrates, with a dark red line, the semiotic distribution of $Sd^{(1)}$ images which the experts used to describe information belonging to two of the five categories of design information in the ODE. The lighter red line denotes the semiotic distribution of images to information at $Sd^{(2)}$. In both categories at both $Sd^{(1)}$ and $Sd^{(2)}$; it is the index and symbol that are the most dominant semiotic characteristics. From Figure 50, the relative confinement to two informational areas, combined with the mixed use of indexical and symbolic imagery, the expert group exhibited a particular pattern regarding the generation of design information. This further suggests that the environment itself does not affect the way in which the expert designer undertakes the given design objective.

From the figures above, the semiotic qualities of Sg , $Sd^{(1)}$ and $Sd^{(2)}$ suggest that the expert group's members applied their experience, by using the icon for analogous purposes, to present content using the indexical and symbolic content in equal measure. The vocabulary of this information is neatly organised into two informational categories and reveals the informational range in which the associative processes are applied to imagery within the ODE.

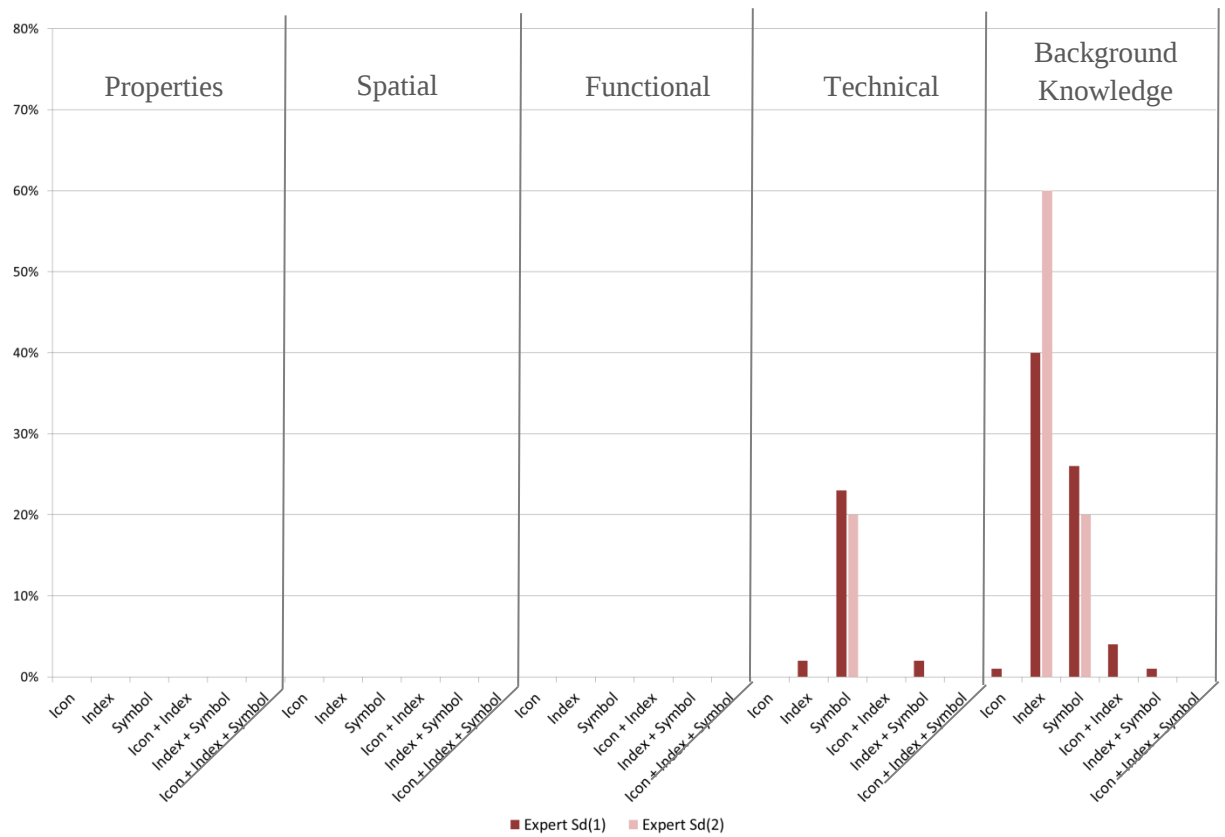


Figure 51 Normalised spread of expert Subclass categories across $Sd^{(1)}$ and $Sd^{(2)}$.

6.2.5 Comparison of iconic information—Sg→Sd⁽²⁾

The generation of design information is characterised by both groups by the introduction of the iconic image at Sg→Sd⁽¹⁾. Figure 52 is a typical iconic image used by the crowd. Often for the crowd, the icon consisted of familiar building-related objects such as solar panels, lights in association with environmental issues, and shipping containers were a particular favourite in association with modularity. Similarly, the experts would import simple iconic images. These were direct images of familiar objects; however, the diversity in the range of iconic content was in contrast to the crowd's selection of images. The experts would import icons which did not consist of items directly related to the construction of a green modular unit. Figure 53 is a typical iconic image of Lego blocks. It was imported by an expert to express Domain Knowledge concerning modularity. Its primary aim was to address the effectiveness of simplistic and repetitive construction techniques in the constrained repetition of modular building systems.

An emerging characteristic of the way in which the generally familiar iconic content was used in both groups, was the level of abstraction between the content and the intended meaning. The relative abstraction of an image is defined by its distance to what it represents. Each representation can be described as concrete or abstract (Wade, 1977). The concrete and abstract headings are two dimensions of the same notational type expressing a distance to what is represented. For example, an iconic photograph is a direct representation of its subject and said to be a concrete (in terms of abstraction) representation. In contrast, a highly stylised portrait is less concerned with accurately representing its subject and more concerned with the artistic impression; the further away from the subject the more abstract the image becomes in relation to the original subject of the image (Wade, 1977). For architectural representations, determining the abstractness is carried out mainly through determining important architectural elements set against the context; in our case the context is established through the requirements of the brief.



Figure 52 Crowd provided icon of solar panels denoting power saving options.



Figure 53 Expert provided image referencing modularity and construction.

The brief requires ideas for affordable housing of a modular and ‘green’ nature. In terms of determining what is abstract or not in relation to the notion of the ‘affordable’, ‘green’ and ‘modular’ housing unit, we look to Maher’s (2006) discussion of creative spaces. Maher (2006) argues that when describing creative processes there is an assumption that there is a space of possibilities. Boden (as quoted by Maher, 2006) refers to this space of possibilities as a ‘conceptual space’. In adapting the notion that context can provide our conceptual space, it can be proposed that the level of abstractness embedded in the imagery used in our experiment can be qualitatively determined by how abstractly or how concretely it represents the core ideas central to the design theme. In this study, this is the information regarding the design of a modular green home.

6.2.6 Comparison of indexical information—Sg→Sd⁽²⁾

The nature of the information generated by both groups in their respective ODEs is initially characterised by the differing levels of abstraction within the selected icon-to-index transition at Sg→Sd⁽¹⁾. The comparison of semiotic and informational values reveals that, in the ODE, the experts only focus on providing images to support Technical and Background Knowledge-related informational areas and use icons and symbols in almost equal measure (40% and 40% respectively) to do so. In contrast, the crowd’s most prominent information category was Properties, but overall the crowd produced images in relation to every category of design information. This resulted in a more diverse and widespread collection of images that were used to describe all of the components within the informational categories. Figure 54 is a typical image used by the crowd to express indexical meaning about the properties of a particular space. The notion of sustainability was intuitively and indirectly addressed using familiar elements of existing imagery (in this example it is an image of a feature wall with herbs and vegetables). Often for the crowd, the indexical design meaning was typically used to communicate or explore one particular topic in depth. In contrast, the experts imported icons to indexically denote much more conceptually abstract meaning. Figure 55 is a typical iconic

image of Barcelona city's grid. It was imported by an expert to indexically express Domain Knowledge concerning modularity. Its primary aim was to address the physically constrained repetition of modularity. It was not provided as a solution; rather it was provided to stimulate a wider discussion centred on the notion of repetition and its associated possibilities for arrangement.

The complexion and quality of the design meaning was identifiably unique in both groups by Sd⁽¹⁾. For both groups, the imported iconic imagery was used for associative indexical information. This was often characterised by its lower level of abstraction in which its indexical value related very closely to elements borrowed from the depicted qualities of the existing iconic imagery. This was often familiar and consisted of ordinary, immediately recognisable visual depictions of items such as bamboo shoots, tinned paint, and many other existing structures and objects. In the crowd, the diversity of Sd⁽¹⁾ indexical information was presented with a limited lower level of abstraction and each individual tended to use images to indexically refer to solutions by exploring in detail a specific element of the design issue. For the experts, the existing information in the iconic imagery was often much less familiar and consisted of patterns and visual depictions of items, such as new building skins, materials and existing exploded 3D images denoting the variations of modular systems.



Figure 54 Crowd provided iconic image referencing spatial qualities.

²⁵ Image source: <http://www.dailytonic.com/the-heat-is-off-natural-cooling-in-architecture/>



Figure 55 Expert provided iconic image referencing Domain Knowledge.

²⁶ Image source: <http://www.barcelonayellow.com/bcn-photos/176-pictures-eixample>

6.2.7 Comparison of symbolic information—Sg→Sd⁽²⁾

The use of the image to denote divergent types of symbolic content emerged as the third prominent characteristic in both groups. The Symbolic information in the crowd was expressed using illustrations that were independently created using digital tools and were provided by the more confident members of the crowd. They provided Technical-related images such as small schematic Parti drawings (Figure 56). An even smaller number started by drawing using Adobe Illustrator, to immediately generate symbolic plans and elevations to communicate their idea. In contrast, the expert group increasingly relied on symbol activity to communicate information throughout all three transitions, which was much more evaluative and conceptual. As the task did not emphasise the need for a direct design outcome, the symbolic imagery used in the expert group between Sg and Sd⁽²⁾ displayed highly abstract qualities that could be associated with the type of abstract activity found in the early stages of a design project. The symbolic imagery exhibited similarly vague and abstract characteristics to the experts' use of the icon and index and remained equally vague in its analogous expressiveness (Figure 57). The experts, who have developed particular knowledge structures, employed a wide range of imagery to abstractly express vague symbolic associative content. This content was aimed at communicating a search effort, and due to the high level of abstraction expressed by the associative reasoning, the abstractness of the symbol supported a search effort where a fertile metaphorical 'problem space' was being generated and solutions could potentially be found (Casakin, 2004). These findings correspond with Chase and Simon's (1973) studies regarding the differences between experts and novices involved in various problem-solving activities. This suggests that through the relatively broad use of imported symbolic imagery to describe abstract concepts, the expert group exhibited within the ODE, behaviour closely associated with what the literature characterises as the early design stage analysis and exploration of the issue.

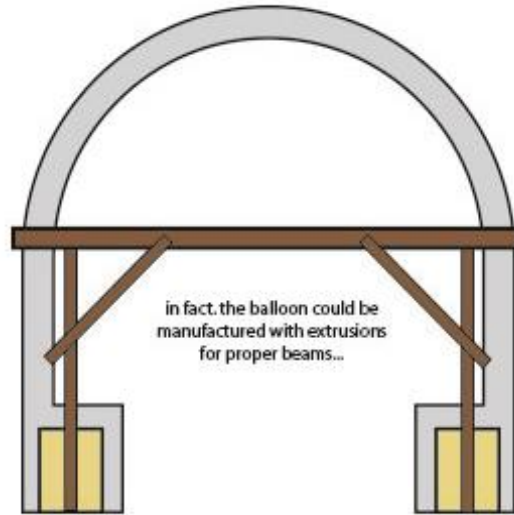


Figure 56 Example of the concrete symbolic image used in the crowd group.

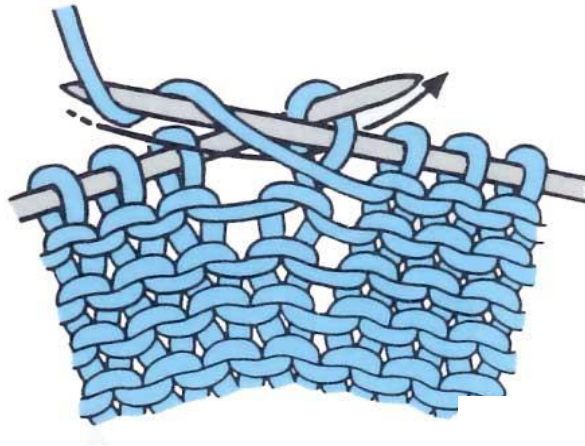


Figure 57 Example of an abstract symbol used in the expert group.

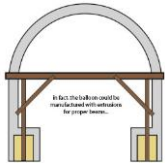
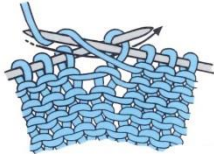
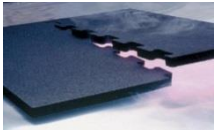
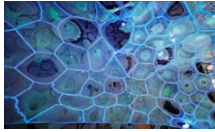
²⁷ Image source: The crowd symbol example was authored by a crowd member using Adobe tools.

The consistent presence of symbols over the three transitional stages of $Sg \rightarrow Sd^{(2)}$ suggests that the crowd group had a pictorial understanding of the schematic notational conventions used by experts. This was characterised in the crowd by a solution-based approach centred on the 'green' issue. These schematic solutions support Casakin's (2004) findings in which novices tended to focus on solutions in a less abstract and more direct way. Furthermore, the symbols support Casakin's (2004) findings in that the symbolic images were "characterized by a low level of detail". In his study, Casakin (2004) identified that symbolic images are used to generate analogies that "helped novices (the crowd) to expand its explorations in the 'problem space' " (Newell & Simon 1972). This can be directly mapped to a collective design context and the effect of this enhances the synthesis of different solutions which were shared within the ODE. The experts on the other hand, armed with particular knowledge structures, employed a wide range of abstract imagery in order express vague symbolic associative content. This content was aimed at evaluating the parameters and concepts involved in modular design. For the experts the use of symbolic imagery was closely associated with an exploratory approach. The result of this approach revealed a high level of abstraction embedded in the relationship between the actual image and associative reasoning the image was representing. The symbol provided abstract meaning which contributed within the ODE to a fertile metaphorical 'problem space' that was being generated within it. The activity exhibited by the experts in the ODE suggests that an online environment would not restrict the individual design activity that is commonly associated with experts when undertaking a design task in an offline and individual context. Expert designers develop a highly formalised notational system over time to handle the communication of various types of information from the start of the task, where the images are often vague and abstract (conceptual exploratory and sketch like), to the final stages where the notational systems used are more concrete and defined (plans, sections and elevations) (Wade, 1977). The experts in this study were observed to use icons in the production of vague and expressive information. This type of activity is often

associated with start of the task, where experts commonly use the images in a vague and abstract manner to convey conceptual and exploratory information.

To demonstrate the comparison between groups in terms of how the images are used to support the generation of meaning, the Figure 58 provides a range of typical examples of the type of images that the crowd applied for the purpose of describing meaningful design content within the ODE. In Figure 58 the main heading in each row represents the Major category with an example image. This is followed by the image with its subclass value and its design related semiotic value(s). The aim of Figure 58 is to comparatively demonstrate the range of typical examples of the type of images icons, indexes and symbols which the crowd and experts applied for the purpose of describing meaningful design content within their respective ODEs.

Figure 58 Comparison of imagery, associated semiotic and informational values.

COMPARISON OF REPRESENTATIONS	
CROWD	EXPERT
PROPERTIES	
	NONE
Spaces - Icon	
SPATIAL	
	NONE
Global relation - Index	
FUNCTIONAL	
	NONE
Activity - Icon	
TECHNICAL	
	
Diagram - Symbol	Diagram - Symbol
Background knowledge	
	
Domain Knowledge (Icon)	Domain Knowledge (Icon)
	
Metaphor (Index+Symbol)	Metaphor (Symbol)

6.3 SUMMARY AND DISCUSSION

From the comparative analysis above, two key characteristics emerge. The first characteristic to emerge in both groups was the process of borrowing the existing qualities of icons to express index and symbol based content (called *Abduction*). The second characteristic to emerge in both groups was informational movement as revealed by the semiotic transition itself.

- ***Abduction***

Both groups produced design-related information in a process which involved borrowing the qualities of icons to express index and symbol-related design content. The process of intuitively or intentionally borrowing existing features of iconic imagery to express abstract meaning indexically, such as ideas, is described by Peirce (CP 3.433) as a reasoning process he called abduction. Abduction is crucial for the creative process because it enables the individual to reason upon elements embedded within existing iconic imagery in order for them to be isolated and borrowed or combined to communicate things that otherwise do not yet exist. The abductive process of the borrowing of qualities was a shared practice in both groups but it was within each group's abductive processes that there were observable differences in the range of information and the levels of abstraction by which that information was conveyed. For the expert group, there was a much higher level of abstraction within a narrow informational framework in contrast to a much lower level of abstraction and a much wider informational framework in the crowd group. The semiotic distributions and the levels of abstractness by which these informational values are conveyed suggests differences in the experts' vs. novices' thinking within the collective design context of this study. These differences are reviewed in Chapter 7.

- ***Transition***

The second characteristic to emerge was the presence of the semiotic transition itself. The transitions between Sg, Sd⁽¹⁾ and Sd⁽²⁾ in both groups provides evidence that, within the collectively oriented ODE of this study, there was an

unmediated movement of design meaning. Both groups behaved similarly by continuing to generate meaning in the ODE based on images, other than their own, with previously established design-related meaning. This transitional semiotic pattern was native to both groups and revealed that the crowd, as well as the experts, used the image for not only generating, but independently reviewing, evaluating, and eventually extending the original design-related content by adding more analogous meaning to it. Individually, members within the crowd in the ODE were capable of expressing design meaning through imagery. Furthermore, the existence of movement beyond the initial generation of design information implies that there was a capability for the crowd to engage in the development of an extended design dialogue in a collective setting such as an ODE and is reviewed in Chapter 8.

As expected, the crowd relied on importing numerous representations in an effort to express design information over the duration of the design session. This implies that the crowd used, in a Piercean sense, an associative, abductive process to creatively generate design knowledge in order to contribute information to a problem space. To this end, both groups similarly used the ODE in the design session to express, communicate and share the outcomes of associative design reasoning. The abductive reasoning processes, to varying degrees of abstraction, consisted of expressed intuition, trains of thought, inquiries, questions and arguments. This implies that experts and the crowd were both using representations in the ODE context to generate design knowledge. This opens up the possibility for the development of web-based platforms to accommodate a larger participant base. Furthermore, these results might imply that there is a potential for capturing the creative abductive output of the crowd in such contexts.

The following two chapters address the two main areas outlined above. Chapter 7 presents an analysis of methods of representational use and characterise the types of information generated, Chapter 8 presents an analysis of the movement of the design information over the $Sg \rightarrow Sd1 \rightarrow Sd2$ transitions, and Chapter 9 will discuss Chapters 6, 7 and 8 in greater detail.

Chapter 7: Characterising information

As identified in Chapter 6, the expert and crowd groups used external imagery to generate varying ranges of design information. This chapter explores in more detail the patterns involved in the largest transition and presents a deeper analysis of the initial importation of imagery from Sg to Sd⁽¹⁾. The result of this initial transition in both cases was the generation of large amounts of design-related information for both groups. Once the images were in the ODE they remained in place and, by their coexisting proximity within the ODE to other images, they revealed a larger and more complex set of relations. By establishing a primary set of complex relations (at Sd⁽¹⁾), an initial baseline of design knowledge was generated. Once the initial transitional movement of Sg→Sd⁽¹⁾ had taken place, any subsequent interactions with existing Sd⁽¹⁾ images cumulatively generated additional, associative information and is the subject of the following chapter (Chapter 8).

7.1 ANALYSIS METHOD: CUMULATIVE ANALYSIS.

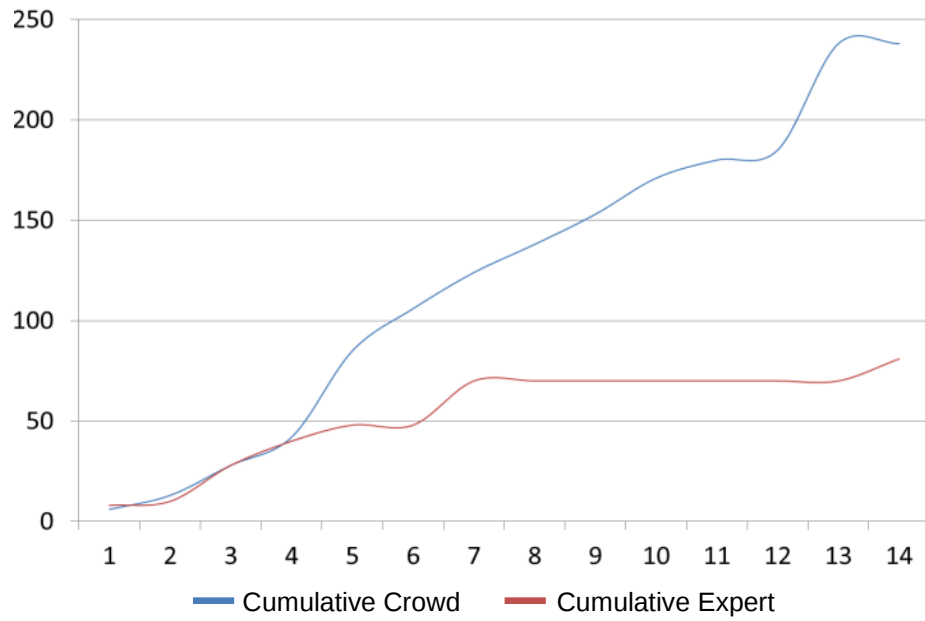
In this chapter a cumulative comparative analysis is used to calculate and compare the combined value of the aggregated semiotic and informational data. A cumulative comparative analysis is a method which measures the relative design effort of participants over a session, by calculating the accumulative occurrence of a value between a low value starting point and a final accumulated total (Gero & Kannengiesser, 2014). The measurement methods in this comparative analysis are adopted from Gero and Kannengiesser's (2014) study on the cumulative analysis of multidisciplinary designers' behaviour. The measurements are based on the cumulative occurrence of the semiotic values, the informational values and transitional values across a 14-day, permanently open, web-based design session. This will enable a description of both the crowd and expert groups' relative design effort in the ODE and reveal any differences or similarities in the design activity of both groups.

7.2 INFORMATION GENERATION—Sg→Sd⁽¹⁾

Figure 59 provides a numeric (a) and normalised (b) comparative illustration of the cumulative addition of images as they are uploaded into the design space by members of both groups. Both the numeric and normalised Figure 58 (a) reveals that during days one to four, both groups populate the design space with images at a similar rate. The crowd's activity steadily increased the amount of images at a rate of 17 images per day, every day and was in contrast to the expert's activity. From day four onwards the expert group marginally increase the amount of images in their design space and from day seven onwards there are no more images added until day 14 ending with a total of 81 images. The average daily contribution when aggregated over a 14-day period shows that the experts contributed an approximately 11 images per day; however, this activity only occurred over a space of seven days. Figure 58 suggests two characteristic yet divergent patterns. The first is a pattern of similarity in that both groups use imagery at a similar rate during the initial Sg→Sd⁽¹⁾ transition. The second pattern shows a difference in activity in both groups in which the experts participated on only six of the 14 days in contrast to the crowd, which participated every day over the 14 days. This might suggest different approaches to the design process from both groups, or may just represent differences in motivation to participate regularly.

As established in Chapter 6, the types of images used by the expert group were revealed to express information of a more abstract nature than the crowd group. In the crowd group the image was often used for a more direct type of referencing of its qualities to communicate a greater diversity of information. As a result the information appeared much less abstract in the crowd group. Both groups did similarly use the image to construct a semantic meaning and express design information about the 'as yet to exist' object(s) or building(s) in a creative way, (by means of design).

(a) Numeric



(b) Normalised

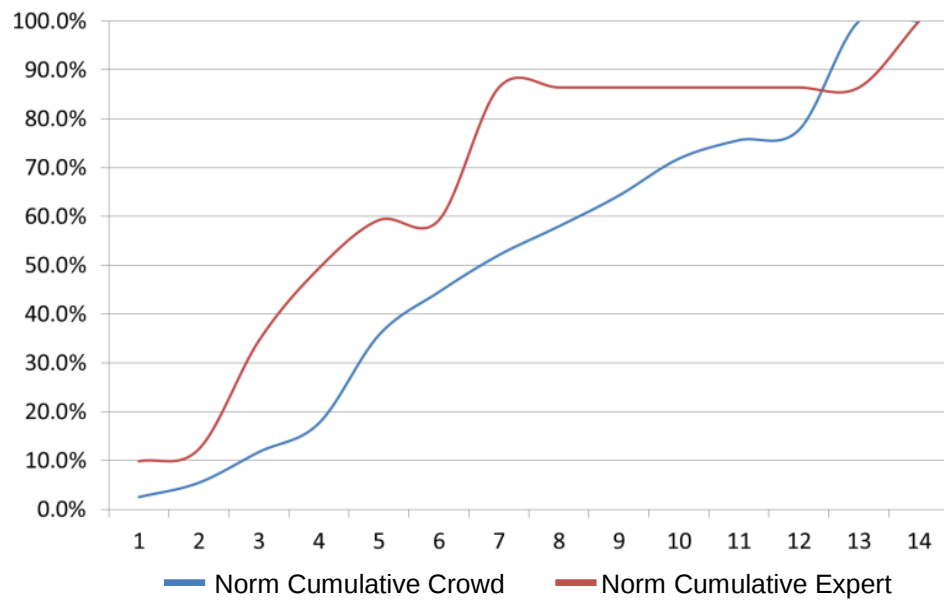


Figure 59 Trendlines showing $S_g \rightarrow S_d^{(1)}$ patterns of image introduction.

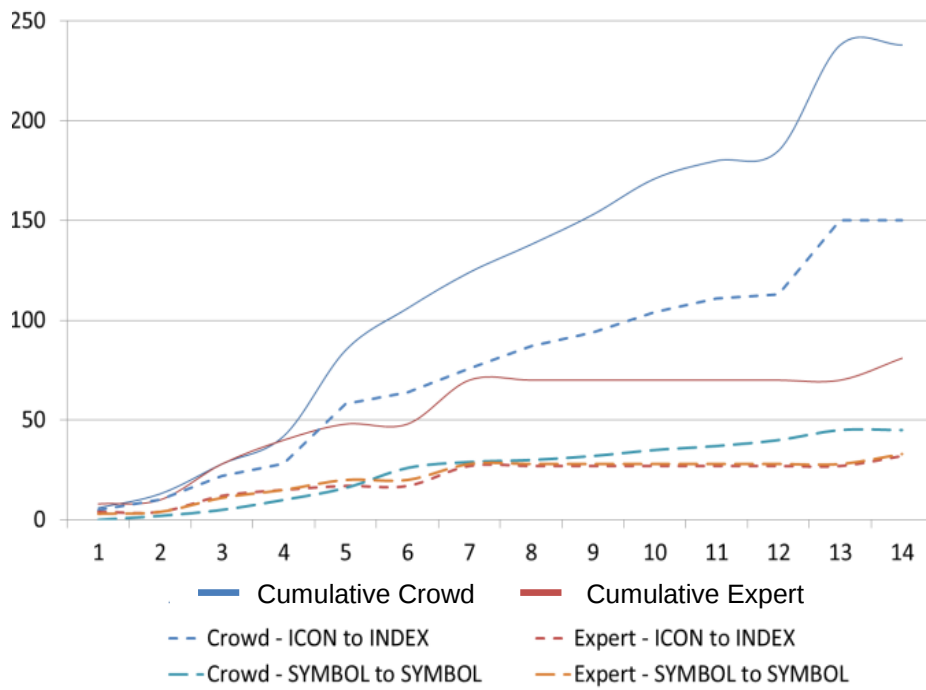
The proportionally balanced distribution of images at $Sg \rightarrow Sd^{(1)}$ in both groups might suggest that there was little difference between groups in recognising the need, and acting on that need, to produce an initial body of design meaning. To achieve this, both groups chose to import an array of iconic representations to help produce the initial body of design information ($Sg \rightarrow Sd^{(1)}$). Similarly both groups borrowed of elements from 'ordinary', 'familiar' or 'constructed' images upon which new design-related information values were projected within the ODE, to varying degrees of abstraction. The patterns involving the introduction of images to establish an initial body-design meaning does not appear to be a discipline specific exercise, due to the participants of both groups undertaking similar activity whereby the image is imported for the purpose of the production of information.

7.2.1 Top-down vs. Bottom-up

The main observation from this comparison is based on the observation of the semiotic distribution between the crowd group and the expert group. A point of interest is revealed in all of the trendlines in the normalised Figure 60 (b). Figure 60 (b) shows that at day 14, there is an almost perfectly matched combination of the Index and Symbol in the expert group. When viewed in comparison with the crowd distribution, this falls exactly halfway between the crowd's use of index and symbols.

Figures 60 (a) and (b) present a numeric and normalised (respectively) cumulative distribution of the main semiotic transitions from $Sg \rightarrow Sd^{(1)}$ over a 14 day period. For the expert group, Figure 60 (b) (normalised) shows the indexical (33.5%) and symbolic (40%) meanings (demonstrated by the red coloured grouping of dotted graph lines) are evenly distributed. For the crowd, the semiotic distribution of indexical and symbolic meaning is more widely dispersed (demonstrated by the blue coloured grouping of dotted graph lines).

(a) Numeric



(b) Normalised

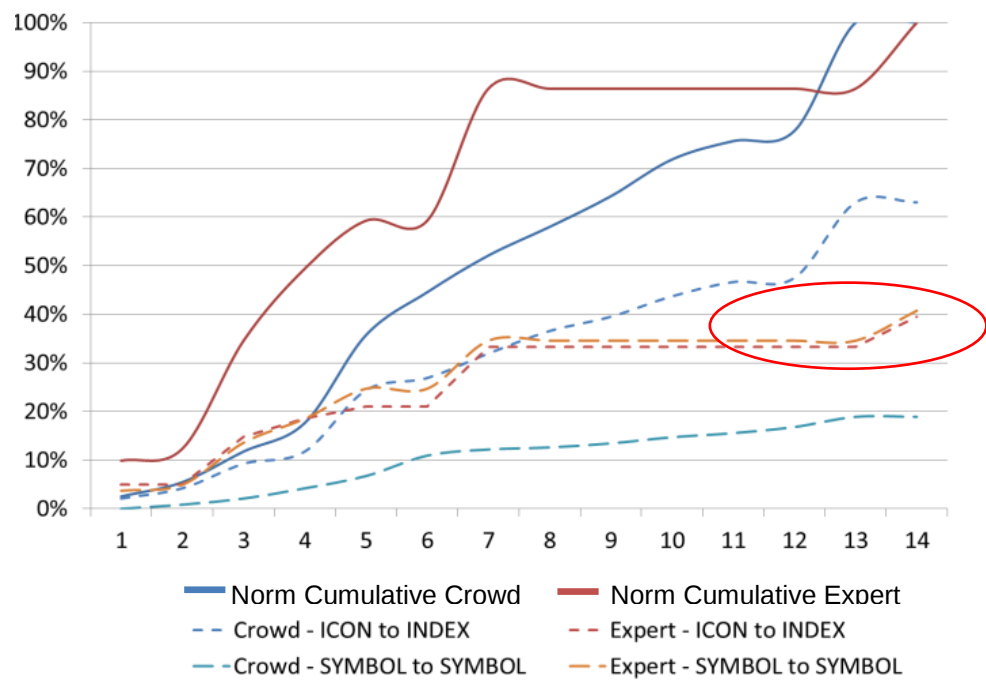


Figure 60 Trendlines showing semiotic values over $Sg \rightarrow Sd^{(1)}$ transition.

Figure 60 (a) shows that for the crowd, Indexical meaning (overall 63%) was the leading semiotic method for generating meaning. However, second to this, graph (b) presents the next largest contribution by the crowd which was symbolic imagery (overall 18.9%). Almost exactly at the midpoint between the upper indexical and lower symbolic crowd limits is the experts' combined indexical and symbolic representations.

The characteristics of meaning generation seem to differ in both groups. The crowd saturated their environment with a highly unbalanced proportion of existing indexical and self-generated symbolic imagery (60% and 20% respectively). The crowd exhibited a capacity to express design meaning through using a wide array of indexical meaning, based on directly drawing from the qualities of the image, as well as producing rudimentary sets of symbolic design representations (plans, sections and elevations). The expert participants used a highly proportioned balance of interlinked symbolic and indexical imagery (34% and 40% respectively) to communicate design meaning. The experts expressed indexical meaning in parenthesis with symbolic meaning (although none were created specifically for this design task, as opposed to the crowd). This combination of imagery (as described in Section 7.1) was generated to compliment a vague and abstract exploration of the design issue. This characteristic is often associated with expert activity (Cross, 2004). It is also described as a top down, analytical and problem-decomposing approach (Cross, 2004). The bottom up activity of the crowd might reflect a reinforcement of lower order exploratory behaviour, in contrast to the narrowly focused, analytical, top-down activity of the expert participants.

7.2.2 Depth vs. Breadth

Figures 61 and 62 comparatively illustrate the differences in the distribution of the crowd and expert design information as it was cumulatively generated over three transitions during the extended 14-day design session. For the crowd, the information was distributed across all five categories: Properties, Spatial, Functional, Technical and Background Knowledge. For the experts, this was distributed between two categories: Technical and Background knowledge.

The leading characteristic to emerge from the icon to the generation of index related information from $S_g \rightarrow S_d^{(1)}$ is the divergence in the abstracted information generated by both groups. Both groups are statistically comparative in their use of representations; however, both groups use the representation in a manner that produces different informational outcomes.

1. Crowd outcomes—the ‘Depth-first’ approach in the ODE.

Chase and Simon (1973) carried out a cornerstone study on differences in expertise between chess players. They observed that novice chess players conducted an exhaustive search through both relevant and irrelevant knowledge in a ‘problem space’. However, master chess players demonstrated their awareness of those narrow sectors in which their exploratory efforts would potentially lead to more promising outcomes (Casakin, 2004). Filtering through to the fields of design, these observations have been mapped and well explored in describing the differences between novice and expert designers (Ahmed, 2003; Akin, 1987; Casakin, 2004; Cross 1999, 2004). The difference between novices and experts is described neatly by their two differing approaches to the problem of design. Novices will often pursue a ‘depth-first’ approach to a problem—sequentially identifying and exploring subsolutions in depth, and amassing a number of partial subsolutions which then somehow have to be amalgamated and reconciled, in a ‘bottom-up’ process (Cross, 1982).

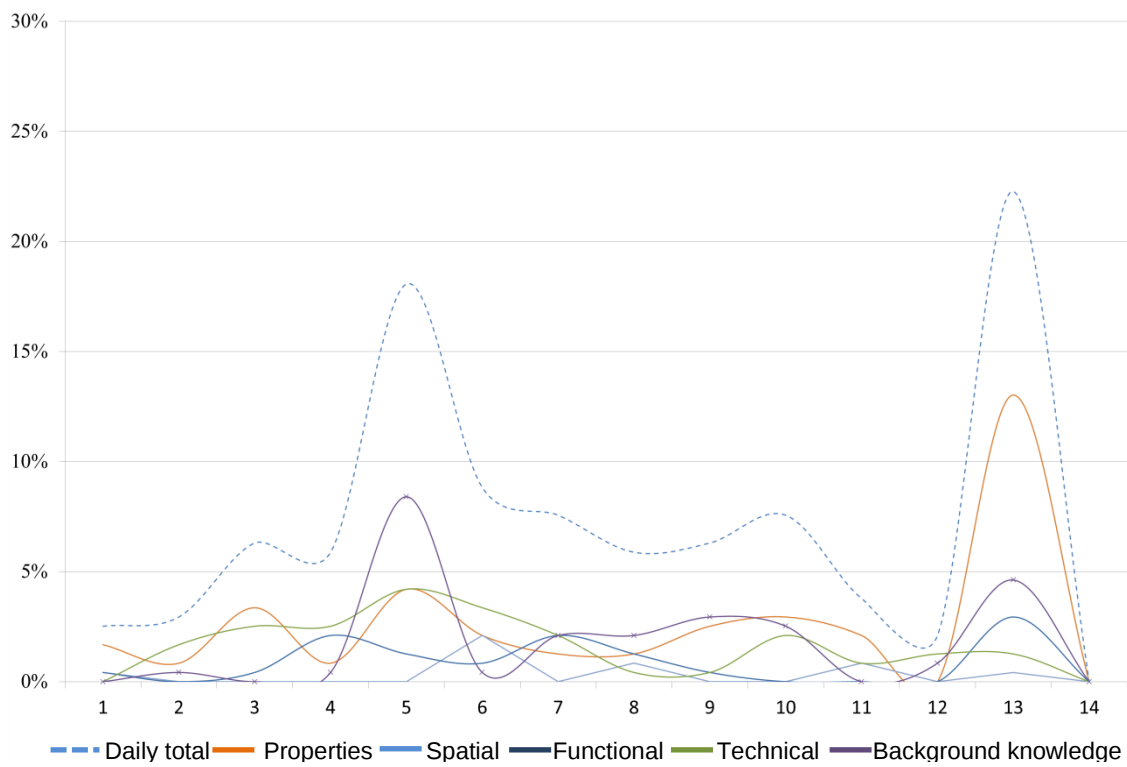


Figure 61 Normalised spread of crowd informational categories over 14 days.

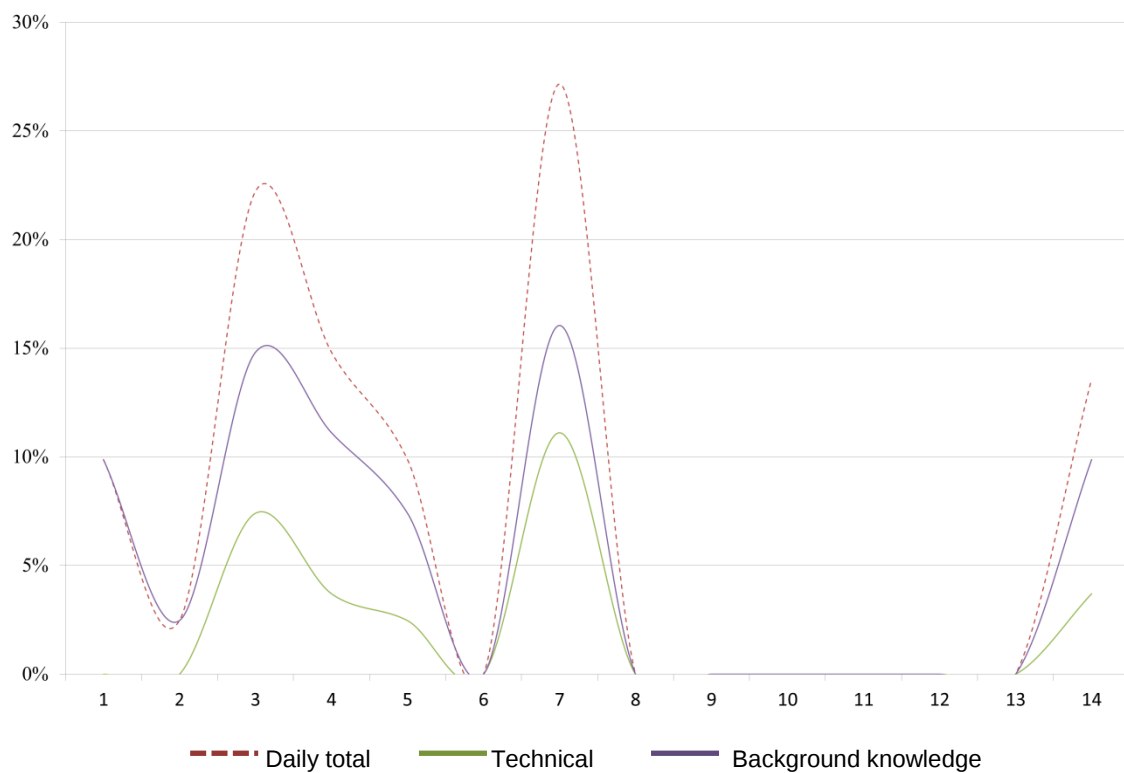


Figure 62 Normalised spread of expert informational categories over 14 days.

On the other hand, “experts usually pursue predominantly ‘breadth-first’ and top-down strategies, and are more willing to reject an early solution when it is discovered to be fundamentally flawed” (Cross, 1982, p.27).

Figure 63 shows typical examples of the iconic and symbolic imagery used in the crowd group in the generation of indexical and symbolic analogous information. The crowd, in a wide-ranging search for solutions, generate an extensive array of information which ultimately is diverse enough to encompass the entire informational range. This activity is reflected in the crowd’s use of representations to generate information spanning all five categories (Properties 44%, Spatial 4%, Functional 8%, Technical 23% and Background Knowledge 21%). However, these solutions were conveyed with limited detail and are characterised by their direct relation to the content of the image, producing a low level of abstractness to the information. The use of the image for mainly producing solution-based indexical and symbolic analogies within the ODE helped the novices to expand their explorations in the ‘problem space’. Cross (2004) and Casakin (2004) define this bottom-up solution-based activity as the ‘Depth first’ approach to design.

2. Expert outcomes—the ‘Breadth-first’ approach in the ODE.

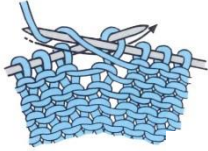
In contrast, the images in the expert group were provided to stimulate a wider discussion centred on the notion of repetition and its associated possibilities (Figure 63). The representation in the expert group at $S_g \rightarrow S_d^{(1)}$ was typically used in a vague and abstract manner. Most often it was closely associated to analytical activity. This type of abstract analytical activity is often associated with expert activity and defined as the ‘breadth-first’ approach when involved in solving design problems (Cross, 2004).

The experts, who have developed knowledge structures, employed a wide range of imagery to abstractly express symbolic associative content. This content was aimed at communicating a search effort, and due to the high level of abstraction in the associative reasoning, the abstractness of the symbol supported the search effort where a fertile metaphorical ‘problem space’ was

generated, where solutions could *potentially* be found. These findings also correspond with Eckersley et al's., (1999) and Casakin's (2004) studies regarding the differences in visual analogies between experts and novices.

The experts' use of representations in the ODE generated information spanning only two categories (Technical and Background Knowledge). In Cross's (2004) 'Breadth-first' approach, the expert typically engages with a design task by selecting relevant areas of the design problem for analysis. In the early stages this is often characterised by using imagery to explore the wider implications of the problem. This is often achieved by using a higher level of conceptual abstraction to encompass an initially wider analytical breadth to extract the relevant parameters of the task at hand in a top-down, 'breadth-first' process.

Figure 63 Images used in the bottom-up and top-down approaches.

Crowd Images expressing bottom-up content		Expert Images expressing top-down content	
	A typical example of the concrete symbolic imagery used in the crowd ODE.		Expert provided image referencing modularity and sustainability.
	Crowd provided image referencing sustainability.		A typical example of the abstract symbolic imagery used in the expert group.

7.3 SUMMARY AND DISCUSSION

Results of the analysis so far have revealed that the experts and the crowd similarly used the icon for indexical and symbolic associative reasoning processes in the ODE. Using the coding scheme developed for this study it was possible to map the distribution of the iconic, indexical and symbolic values to the design information values over the stages of Sg through to Sd⁽²⁾.

- ***Experts ‘breadth-first’ design activity in the ODE***

In the ODE, the experts engaged with the design task by using a mixture of qualities found in general iconic and symbolic representations to abstractly reflect components considered key to the design task. By extracting various qualities of imagery in seemingly vague and abstract ways, a deeper, more explicit problem-decomposing strategy became evident. This approach was less concerned with a final solution; instead the imagery was used to define the parameters of the problem (Cross, 2004). In design literature this is often described as a ‘breadth-first’ approach (Cross, 2004). By decomposing the design problem, and by using iconic representations to infer analytical components, a much higher level of abstract indexical meaning was engendered in the imagery. Using Suwa and Tversky’s (1997) design categories, analysis showed that the experts predominantly drew on Technical information and Background Knowledge. In a collective context such as that established by the conditions of the ODE, this ‘breadth first’ approach translates to ‘top-down’ activity, because, due to the seemingly ordered and analytical nature of the information provided at an individual level, the cumulative effect was the generation of a much narrower range of information.

- ***Crowds ‘depth-first’ design activity in the ODE***

In the crowd, each participant performed similarly in their contributive behaviour. The design meaning expressed intuitively was isolated to their scope of design knowledge and insight into certain individual elements of the task. For the crowd, the representation was used to express a meaning which, when combined cumulatively, generated a different range and type of information to the analytical information generated by the experts. By using their individual reasoning processes, they generated a themed or schema-based meaning to their design space. The associative borrowing of elements from ‘ordinary,’ ‘familiar’ or ‘constructed’ images to generate analogous design meaning was the predominant feature of activity that arose in the absence of any formal design code or set of design-related rules (Bonollo, 2011). This meaning was further characterised by its attempts at exploring in depth solutions that focused

not on the issue at large, but focused on individual elements, or subissues. When combined, these informational chunks used substantial amounts of iconic imagery to express indexical meaning to produce information which covered all of Suwa and Tversky's (1997) Properties, Spatial, Functional, Technical and Background knowledge design information categories. The cumulative result was that by $S_d^{(1)}$, each participant's contribution was different, and had fulfilled every subclass of Suwa and Tversky's (1997) design information categories. This may indicate that, despite their experiential differences and abilities, each group used iconic representations to intuitively express a range of considerations within the ODE. Each of these considerations shared very similar characteristics to that of focusing on the subproblems of the design issue.

In summary, the crowd exhibited characteristic behaviour identifiable with a bottom-up strategy producing a low amount of analytical associations with the imagery used but a much wider range of information. These differences imply that while the expert group is undertaking the task and producing a top-down higher order level of thinking within the ODE, the crowd is conversely taking a lower order, bottom-up approach. In contrast to the experts appeared to abductively produce an array of abstract analytical information with the icon to index and symbol process; the crowd appeared to be more comfortable producing an array of less analytical and more solution-focused information with the predominantly icon to index process. The resulting difference was that the expert group exhibited characteristic behaviour identifiable with a top-down approach. The result was a saturated ODE with a high amount of abstract analytical information with a narrow informational range.

The implications of these results, if they are found to be generalizable, are that both groups used the image to support differing abductive approaches to design reasoning in the ODE. The research communities of philosophy and artificial intelligence (AI) (Flach & Kakas, 2000) have been fertile ground for research on abduction. However, despite the notable works of Aliseda (2006) and Magnani (2010), there has been no comprehensive model of the process of abduction.

This study of design in a collective context focuses on representations and reveals the sharing of abductive reasoning process as they occur in both groups. According to Tohmé, Caterina and Gangle (2015):

One of the main goals in AI is to design a full architecture able to perform something like the three kinds of Peircean inference. One of the hardest tasks is, of course, to build an abductive engine. The question to be raised by a logician in the Peircean tradition is how to accommodate the third type of inference, *qualitative induction* or *abduction* (p.80).

An understanding of abductive reasoning processes in a collective creative context might open up ways to address the difficulties faced by AI researchers in the modelling and capturing of abductive reasoning. This might be achieved by proposing that, with collective systems, it is the human intelligence and creativity enacted within the digital collective design systems that might provide a potentially unique approach to capturing Peirce's third type of inference; abduction. By producing a hybrid collective/artificial intelligence whereby abduction is not completely arithmetically modelled, but partly captured from collective design processes it might be possible to compliment the inductive and deductive models of logic provided by current AI systems.

Chapter 8: Characterising movement

Transitional values of the image are effected by the interactions which take the image from an external (Sg) value to further related contexts of $Sd^{(1)}$ and $Sd^{(2)}$. By presenting an analysis of these interactions, it is possible to capture and quantify the movement of design meaning within the ODE. The following sections detail the various activities contributing to these shifts in semiotic value. Through developing an understanding of the transitional activity, a number of patterns have emerged.

8.1 ANALYSIS METHOD: QUANTITATIVE COMPARISON

Using the data presented in Table 5.18 (Chapter 5), this chapter provides a quantitative comparison of the transitional values. It begins with a description of how the interactions occurred and caused the transition of semiotic and informational value. This is accompanied by a quantitative comparison of the transitional values as they occurred during the 14-day open design session. The aim of the comparative analysis is to identify unique patterns, differences and similarities in the flow of design information between groups within the collective ODE context of this study.

8.2 INTERACTIONS

In both groups, the movement of design meaning over time was calculated according to the coded transitional values of $Sg \rightarrow Sd^{(1)}$ followed by the shift in values from $Sd^{(1)} \rightarrow Sd^{(2)}$. Articulating these values reveals the evolving chronological semiotic values in shifting design meaning. To organise the timeframe over which these transitional changes occurred it was necessary to categorise the interactions according to two points. The first point was when an image(s) was inserted into the ODE; the second point was when it was subsequently engaged with. For example, if an image was inserted on day three and interacted with on day five, it took the duration of two days before an interaction occurred. As such, the categories are divided over time between short-, mid- and long-term durations. Over the 14-day experiment, the short-

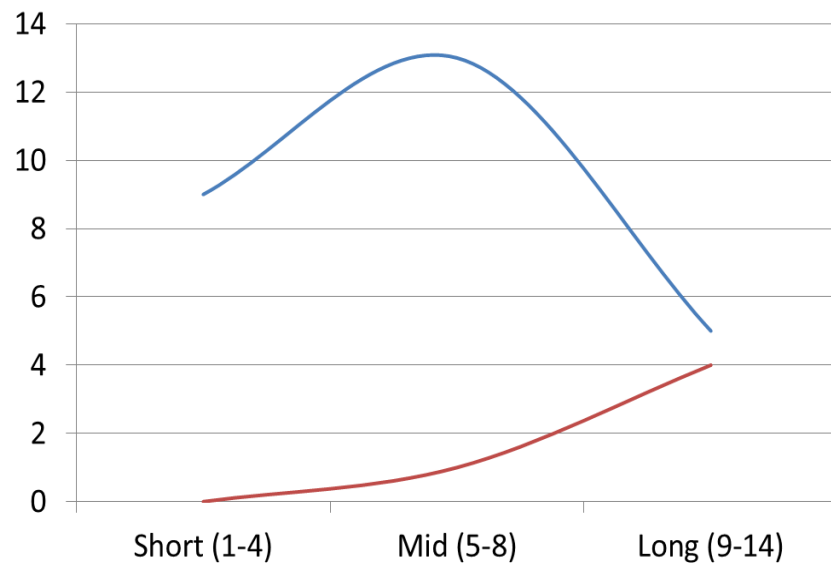
term interactions produced transitions between 1-4 days; the medium-term interactions between 5-8 days and the long-term interactions between 9-14 days. Section 8.2.1 discusses these values in more detail.

8.2.1 Sg→Sd⁽¹⁾

Figures 64 (a) and (b) illustrate the distribution of transitional semiotic activity. For the crowd group, nine transitions (33%) occurred within 1-4 days. A peak of 13 transitions (40%) occurred between 5-9 days and five (25%) of the remaining transitional activities occurred between 9-14 days. For the expert group there was 0% activity between 1-4 days. One transition (20%) occurred between days 5-9 and four interactions occurred on the last day, day 14 (80%). These variances in both the numeric and normalised values suggest differing participation patterns. In the crowd distribution the data produces a peak in mid-range activity and a slow upward trend in the expert group (discussed further in the following section)

There was greater transitional activity in the crowd group (1.5 transactions per crowd member over 14 days) compared to the expert group (1.25 interactions). In the expert group, the interactions took the form of a gradually increasing pattern of activity in comparison to the mid-point peak in activity in the crowd group which produced a gradually decreasing pattern. The presence of these semiotic transitional values is important because initially they provide evidence for the movement of design meaning within an unmediated ODE. Moreover the figures suggest that there are observably different patterns to that movement.

(a) Numeric



(b) Normalised

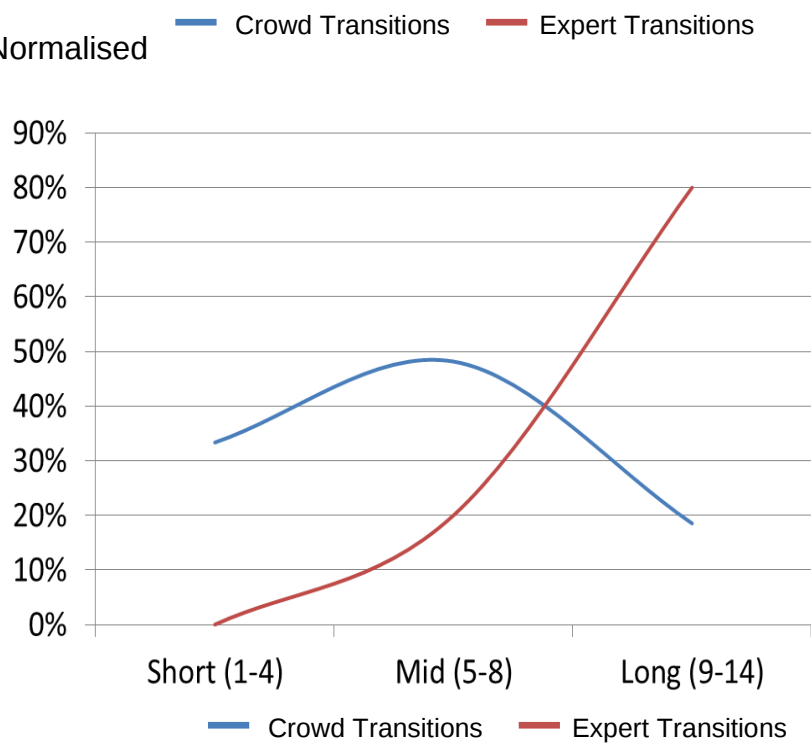


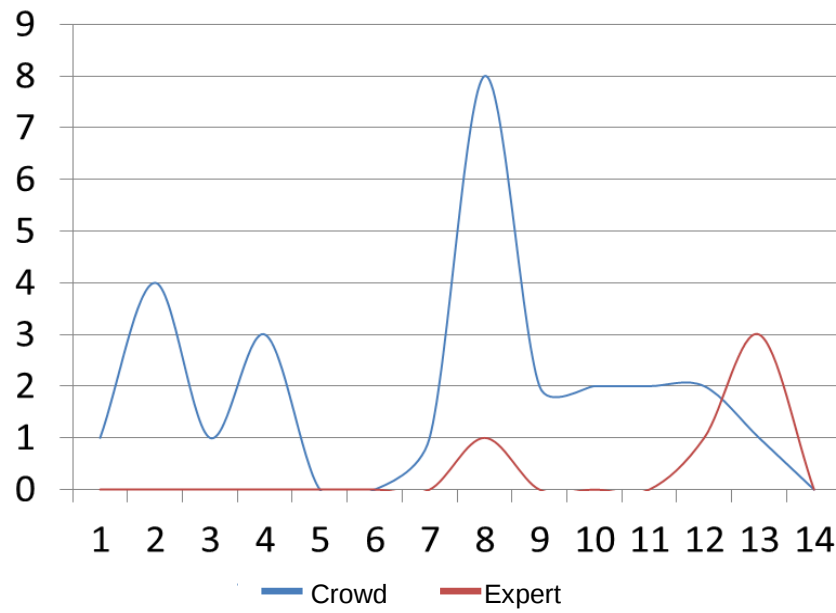
Figure 64 Logarithmic trendlines showing the transitional activity over 14 days.

Figure 65 (a) provides a detailed numeric summary and Figure 65 (b) presents a detailed normalised summary of the three previously described transitional categories of both groups. The average time it took for an interaction to occur in the crowd was 5-8 days. In contrast, the expert group had nil interactions between 1-7 days, one interaction at day 8, and no further interactions until a sharp upward peak of activity on days 13-14.

This difference between groups might suggest alternative approaches to participating in a design task within a context such as the ODE in this study. It might also reflect different expectations of collaborative activity in the expert group in comparison to the members of the crowd, which were not expected to collaborate at all but instead openly and regularly engaged with the imagery over the entire course of the 14-day session.

Because the crowd likely participated without any conventionalised design protocols, they may instead have been applying communication protocols typically associated with social networking practices, such as those reflected in the immediate adoption of the practice of commenting on other participants' images. This behaviour reflects what happens on a social networking site. Despite the differences in duration, it is clear that there are identifiable participatory patterns. Because expert designers traditionally do not design under collective conditions, this might explain the differences between the crowd's consistent activity and the long period of inactivity in the expert group until the last two days. In order to understand the relevance of these patterns, the next section comparatively combines the $Sd^{(1)} \rightarrow Sd^{(2)}$ interaction data values with the $Sg \rightarrow Sd^{(1)}$ interaction data values to reveal any patterns within the activity.

(a) Numeric



(b) Normalised

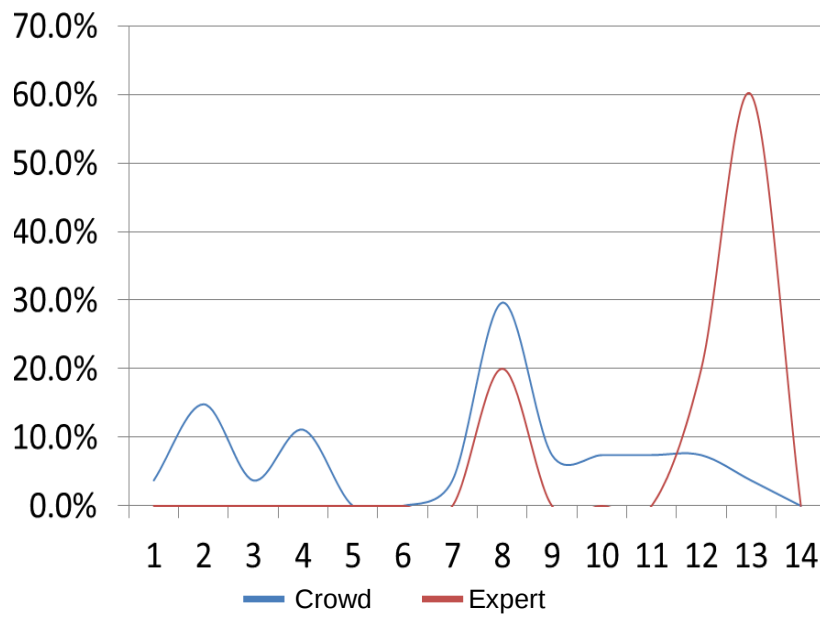


Figure 65 Logarithmic trendlines showing the of interaction peaks over 14 days.

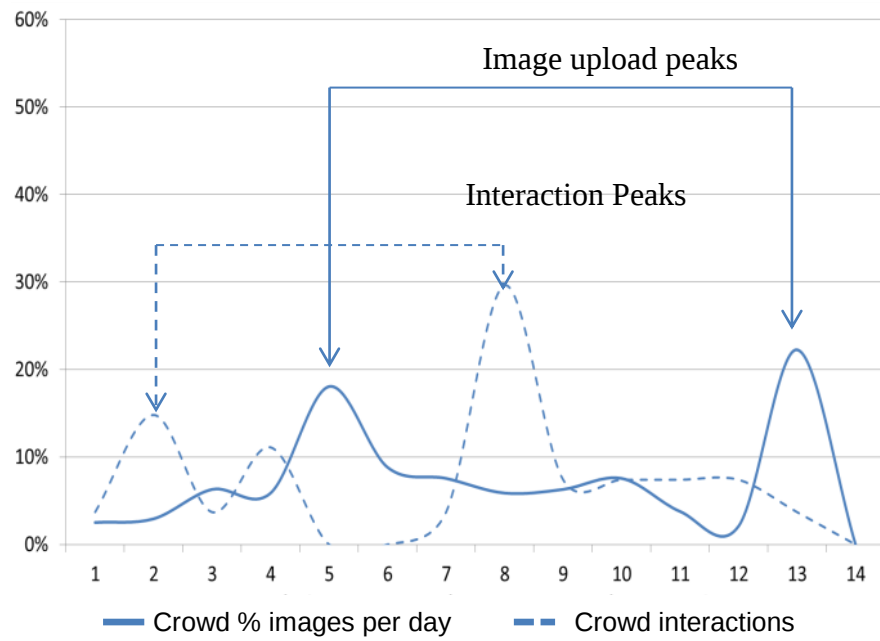
8.2.2 $Sd^{(1)} \rightarrow Sd^{(2)}$

Figures 66 (a) and (b) are comparison of the crowd and expert upload and interaction activity. Each figure presents two values. The solid line value in each figure represents the normalised values for the daily image upload activity ($Sg \rightarrow Sd^{(1)}$ = solid blue line in the crowd graph and solid red line for the expert graph). The dashed line in each figure ($Sd^{(1)} \rightarrow Sd^{(2)}$ = dashed blue line in the crowd graph and dashed red line in the expert graph) is the second value of the semiotic transitions as they arise over the 14-day period. Figure 66 (a) compares the crowd daily image upload amounts (solid blue line) against the transitional shifts in semiotic value that arise (dashed line). Figure 66 (b) compares the expert daily image upload amounts (solid red line) against the transitional shifts in semiotic activity (dashed red line). Both figures suggest a commonality between the crowd and expert group activity in a pattern of interaction following the image upload peaks.

For the crowd, there is a similar pattern of activity; however, the peaks in activity are more condensed in contrast to the experts. For the crowd group, in Figure 66 (a) there is one distinct peak where images are interacted with in the ODE. This peak is directly followed by an image upload peak. Directly following is another interaction peak which again precedes a final upload peak. For the expert group, Figure 66 (b) illustrates two distinct peaks where images are uploaded into the ODE. These peaks directly precede two interaction peaks. This might suggest an 'upload'-'interact'-'upload' pattern differentiated by the time value over which these interactions take place.

Combined, Figures 66 (a) and (b) illustrate that representations were initially used and then reached a point where they were attributed with new design meaning. This sequential movement is relevant to both crowdsourcing and design with evidence that the crowd, similarly to the experts, use representations to support a type of shared activity with regard to a design task in an ODE.

(a) Crowd



(b) Expert

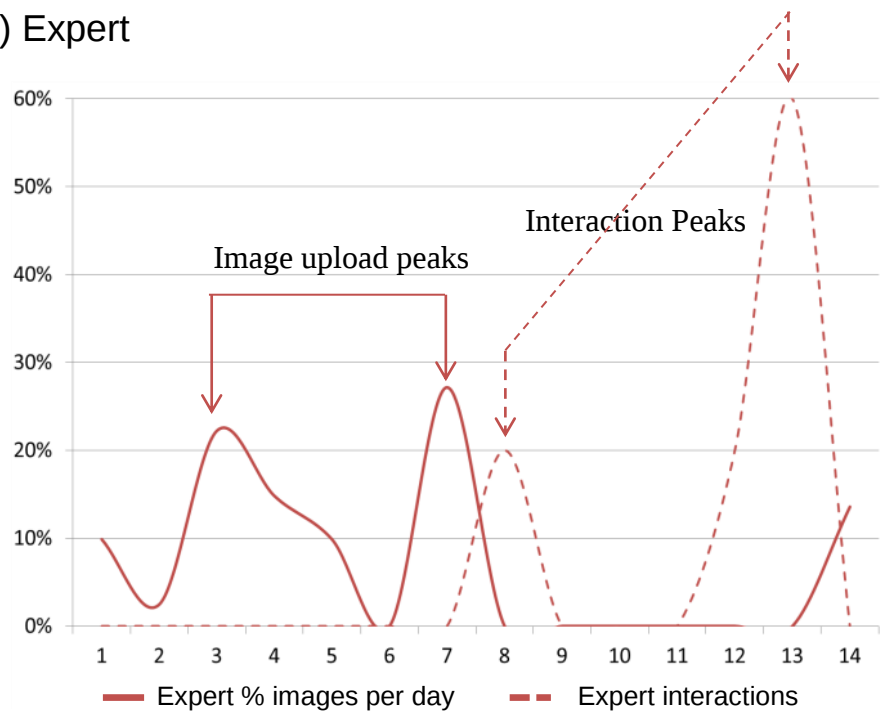


Figure 66 Logarithmic trendlines showing the upload/interaction peaks

Participants in both groups focused on certain images to generate additional meaningful content extending beyond the initial importing of images. Schön (1992) identified a method of design reasoning involving qualitative judgements and described these judgements arising in a process of 'see', 'move', 'see', which he argued is a key component in the sequential nature of design activity. The peaks in Figures 66 (a) and (b) suggest that in both groups this sequence of judgements is taking place in the ODE. Figures 66 (a) and (b) also suggest that, while similar peaks are present, there are varying patterns in the durations at which they occur. The patterns might reflect that the participants of both groups are 'seeing' a particular image and then reinterpreting the qualities of that image in a 'move' to create additional meaning that others will 'see' and reinterpret. In the crowd group, this pattern may be reflected in the regularity between the 'interaction', 'upload', 'interaction' and final 'upload' pattern in the activity. In the expert group, this takes on an 'upload', 'upload', 'interaction' and 'interaction' pattern. In both groups, it is the sequential revisions to existing representations that produces the transitional sequence (reflected by the transitional sequence of $Sd^{(1)} \rightarrow Sd^{(2)}$), producing a movement in design dialogue in the ODE.

8.3 CHARACTERISING INTERACTIONS IN THE ODE

To understand the nature of the interactions we have classified the main observed activities in both groups using the $Sd^{(1)} \rightarrow Sd^{(2)}$ transition. This transition is used because the images are considered already within the design context. Any activities occurring from this point forward can be more accurately represented as design related activity under the ODE conditions, after the initial establishment of information at $Sg \rightarrow Sd^{(1)}$.

8.3.1 Generalising interactions

Even though the ODE was capable of, and provided support for, multiple instances of concurrent collaborative activity, there were no actual recorded instances of intentional synchronous person-to-person communications that produced a movement in design information across the whole study. Movement

of design information occurred based on the type of interactions that took place within each group. In both cases, each group leveraged the visual qualities embedded in existing $Sd^{(1)}$ imagery; however, each group leveraged these qualities to generate design movement in entirely contrasting ways.

For the crowd group at $Sd^{(1)} \rightarrow Sd^{(2)}$, design-movement was achieved by one person directly engaging with another person's image. Movement was generated this way either through a number of approaches; either appending one or number of images to another image, a comment on an image, an image attached to a comment, or simply providing a comment to another comment as a written response to an existing written statement (Figure 66). In contrast, the expert group at $Sd^{(1)} \rightarrow Sd^{(2)}$ only referenced the qualities of other participants' representations for the purpose of supplementing their own personal exploration of the design issue within the ODE (Figure 67). Other than using the items provided by other participants for referential purposes, the experts did not in any way actively engage either with each other or with the work of the other participants.

Figure 67 Examples of *Appending* in the crowd and *Referencing* in expert group.

Sd ⁽¹⁾ Image		Sd ⁽¹⁾ Meaning	Sd ⁽²⁾ Image	Sd ⁽²⁾ Meaning
CROWD		My house Printer		Amusing idea for printing a house is it really going to work. Time between layers, and it cannot stop; each layer must be linked to the previous layer. How do you link the lintel?
Semiotic Value	SYMBOL	<i>Appended to:</i>	Index +Symbol	<i>To question and generate and provide knowledge</i>
EXPERT		The thing that interests me about this setup is the space between the box and the netting.		Reskinning Prototype - membrane has a 30 year warranty; Could be used as external skin to house Level Module; Double wall system could provide insulation requirements.
Semiotic Value	ICON	<i>Incorporated into:</i>	INDEX	<i>To generate further knowledge about building skins</i>

The distribution between groups between *appending* and *referencing* type activity is illustrated in Table 8.1. which characterises each type of interaction as it occurred during a 14-day time frame in both groups. The distribution in Table 8.1 suggests the crowd favoured engaging by outwardly appending information to the existing work of others in order to generate more information, in turn creating movement. In contrast, the movement generated in the experts' group was achieved by only leveraging the visual qualities of other participants' images for the purpose of supplementing an individual approach within the ODE.

Table 8.1 Distribution of values between *Appending* and *Referencing* activities observed.

Normalised Distribution	Crowd		Expert	
	Sd ⁽¹⁾ to Sd ⁽²⁾		Sd ⁽¹⁾ to Sd ⁽²⁾	
	Appending	Referencing	Appending	Referencing
Image to Image	44.4%	22.2%	-	80%
Comment to Image	26.0%	-	-	20%
Image to Comment	3.7%	-	-	-
Comment to Comment	3.7%	-	-	-
TOTAL INTERACTION	27		5	

In both groups, the movement of design information is based on a type of indirect collaboration that is closely associated with collective systems and is described as ‘*Stigmergy*’ (Elliot, 2006).

Stigmergy is a method of communication in which individuals communicate with one another not directly, but by modifying their local, or items within their local, environment. As such it is a logical extension to apply the term to many (if not all) types of Web-based communication (Elliot, 2006).

It is the stigmergic activity that accounted for all the activity contributing to the informational movement of design information in both groups. The abstract indexical and symbolic *referencing* activity of the experts is consistent with the notion of the analytical activity in the expert ‘top-down’ design strategy literature (Ahmed, 2003; Akin, 1987; Casakin, 2004; Chase & Simon, 1973; Cross, 2004). On the other hand, the crowd, who have a lower level of developed knowledge, tended to exhibit an elevated index related behaviour, selected images and appended them with additional meaning at Sd⁽¹⁾→Sd⁽²⁾. The high ratio of index-related imagery and index-related transitions from Sd⁽¹⁾ in the crowd, in conjunction with the diversity of information, suggests that the crowd was exhibiting ‘bottom-up’ behaviour by selecting existing representations to quickly generate and explore solutions to problems. They did this by adding comments and attaching images to existing items to form quick generalisations of the relationship between solutions and problems (Ross & Kennedy 1990). In both cases it is the stigmergic movement of design information, whilst occurring through different approaches in each group, which makes the methods of achieving transitional activity a shared phenomenon within the ODE between

groups. Furthermore, without prior conditioning, the crowd determined the most suitable tool to express design meaning and was equally as likely as the experts to rely on the representational image to support the generation of design meaning, albeit characterised by different processes in each group.

8.4 SUMMARY AND DISCUSSION

In this chapter, we have studied the design activity in the ODE by examining empirical data derived from experiments with expert designers and a crowd. The results of the experiment were coded according to a semiotic and informational value and the transitional changes to these values were captured, showing that the coding scheme is capable of capturing online collective design behaviours in a sufficiently comprehensive manner that can help us to understand the changes in value as design movement activity in the ODE.

By comparing the semiotic data of the expert group and the crowd group in the ODE, similarities were found in that the movement of meaning occurred in both groups. Therefore, we can infer that in an openly shared web-based context, such as the ODE provided in this study, experts and a crowd alike make use of the representation to generate and express additional design thinking based on existing and contextualised imagery. From the comparative analysis above in both sections it is possible to determine two key characteristics. The first characteristic to emerge from the analysis of design information movement is that it occurred through an indirect collaborative understood as Stigmergy, and that these stigmergic movements of information can be characterised, within a collective design context, as *Referencing* and *Appending*.

Having generated the information (via the $Sg \rightarrow Sd^{(1)}$ transition), certain participants began to add new interpretations indexically for the sole purpose of contributing new informational variables to the existing design-related meaning of the image. These interactions occurred on an ad hoc basis over different timeframes. All interactions that took place only occurred through an indirect means in both groups. This revealed that the movement of design meaning did not occur through normal collaborative processes but by the incremental

addition of 'small and discreet chunks' of information applied to existing imagery. This type of interaction is common to collective and web-based systems and is understood as stigmergic collaboration. The stigmergic interactions that took place within the ODE in this experiment can be further categorised into two types of stigmergic interaction: *Referencing* and *Appending*. *Referencing* and *Appending* were two different approaches that informed an indirect type of collaboration within the ODE.

In the expert group there was a shared consistency in the complexity of their 'breadth-first' approach. They acted autonomously and at an individual level and they exhibited identifiable design-related behaviours such as complex abstract top-down problem-decomposing strategies. However, due to the there were no stigmergic interactions between group members based on certain existing $Sd^{(1)}$ imagery. Instead the experts simply used images supplied by other members of the group. At no stage did the experts add any information or comments to existing imagery.

In contrast, the crowd group did communicate with each other indirectly based on certain existing $Sd^{(1)}$ imagery, but did not exhibit behaviour that resembled any established design-related group-oriented collaborative processes. Instead, the crowd favoured a combined approach by heavily appending extra pieces of information to exiting images, often in the form of helpful comments. Or they would also reference certain images with additional comments.

The identified stigmergic transitions in meaning signified a movement of design information following a pattern of Information generation (image upload $Sg \rightarrow Sd^{(1)}$) and the Addition of meaning (Transitions $Sd^{(1)} \rightarrow Sd^{(4)}$). This generation and addition of informational variables revealed that the crowd freely engaged in creatively 'backward reasoning' upon the nature of the problem using other participants' images, whilst simultaneously adding information to their own circle. In design literature, Schön (1983) described a similar activity in which experts engaged. In what he noted as the "designer sees, moves and sees again" pattern of behaviour, Schön offered an insight into the processes of the designer, who "...when working in some visual medium (drawing, for

example), draw associative analogies sees what is 'there' in some representation (Schön, 1983). "[They] will then draw in relation to it, and sees what he/she has drawn, thereby informing further designing" (Schön, 1983). In all this 'seeing', the designer not only visually registers information, but also constructs meaning; he/she identifies patterns, and gives the patterns meaning beyond what might appear to be random and arbitrary lines. Within the experiment environment the observed process of: image-upload, reinterpret (or reason upon), followed by another image-upload, correlates well with Schön's (1983) description of the see-move-see process. The information generation and addition of meaning can be similarly described by the see-move-see concept.

For the crowd, the result of using the icon in this abductive 'bottom-up' manner was that the total sum of the crowd group's activity produced a knowledge base that was far greater than the total of their individual contributions. Emerging from their cumulative activity was an informational range that was described by every category of Suwa & Tversky's (1997) design information categories table. In contrast, the 'top-down' nature of the experts' decomposition strategy revealed that their abductive reasoning generated a fraction of Suwa & Tversky's (1997) design-related categories in comparison to the crowd. This activity had a reciprocal advantage for the crowd. By increasing the knowledge base, they gradually increased the visual richness. This is relevant because design studies have provided evidence that visually rich environments contribute to an increase in creative activity (Goldschmidt, 2004). Novice and expert design activity researchers such as Cross and Cross (1996) and Atman (1999) have characterised this type of generative activity as knowledge generation. The combined effect of the crowds' sharing of information served not only to simultaneously generate a visual knowledge base whilst self-generating its own visual stimuli; but this study shows that the accumulation of these images provided enough stimulus for creative exploration based on certain images.

Chapter 9: Discussion and Conclusion

The role of the representation during an openly shared web-based collective design session has been analysed and presented in Chapters 5 to 8. This chapter is organised with the two hypotheses (Section 1.3) as the structure. Section 9.1 summaries the general results of Chapter 5, which were aimed at testing Hypothesis 1. The subsequent second hypothesis was examined in detail in Chapters 6, 7 and 8. Section 9.2 corresponds to the research results outlined in Chapter 6 in which the shared semiotic characteristics of the design activity are addressed. Section 9.3 corresponds to the research results outlined in Chapter 7 which presents the different characteristics of the design reasoning in the ODE. Section 9.4 corresponds to the research results outlined in Chapter 8 and addresses the shared process of the movement of design meaning. These results are integrated in Section 9.5. The implications and contributions of this research study are presented in Section 9.6. Section 9.7 discusses potential future directions for research and concludes the thesis.

9.1 FINDINGS

The aim of this study was to investigate how, in a collectively shared and open web-based environment, a crowd would express and communicate design meaning. Specifically, this study began with the hypothesis that of all the available types of web-based media, the representation would most likely be the main carrier of design-related meaning. As such, the first hypothesis in this dissertation was that the crowd would, in comparison with an expert benchmark group, exhibit observable differences in the ways the representation is used to communicate in the ODE in general.

To test the first hypothesis, a number of methodological approaches were developed, each presenting their own unique challenges. Firstly, a decentralised web-based environment had to be identified which could simulate the best laboratory conditions in which collective intelligence could occur. Secondly, the recruitment of a crowd and expert group to engage in a design task within the simulated collective environment was needed to provide this study with data. The purpose of the expert group was to provide benchmark

data for a comparative analysis. Thirdly, an interpretive semiotic framework needed to be developed to code the captured data to ensure that meaningful information was generated. Lastly, an interpretive framework needed to be developed to identify the meaning of the information. Combined, these parameters established the necessary framework to support an investigation into the role of the representation in a collective design context.

When discussing collective activity, it is relevant to establish the importance of the reciprocal conditions under which collective intelligence (CI) arises. Within the CI research community it is often noted that one of the fundamental prerequisites needed to support CI is that the environment should not be coordinated (such as those in design crowdsourcing); rather it must be a decentralised system. A decentralised environment provides an individual with the freedom to act autonomously. Without such conditions, a study such as this would rely on data captured from crowdsourcing conditions, which as previously established, are centralised and closed systems which do not provide any freedom to the individual. The result of this would reflect the outcome of collected activity, not collective intelligence. Burns and Stalker (1971) noted that decentralised systems were [most] suitable for innovation due to their unstable, dynamic, organic, non-hierarchical and informal structures. The ODE in this study was selected on the basis of its ability to provide our participants with these well-established characteristics. To this end, the ODE in this study is a strong example of a decentralised system; one in which the individual is provided with access to an online space where each has the freedom to act individually and autonomously. In providing an ODE which met the described conditions, a basis was established for observing the unpredictable nature of a crowd's behaviour, in particular, their *design* behaviour. It is these reciprocal and open conditions that allowed for CI to generate in this study. These conditions became the underlying basis for revealing the role of the representation and its characteristic use in the context of collective design.

Having established the ODE as the laboratory conditions supporting CI, the next step was to introduce a task for both groups. A 'topical' brief was introduced requiring both groups to concentrate on the theme of the problem of housing shortages and environmental concerns. The aim was to elicit contributions

based on subject areas that were bounded by a shared common understanding of the problems involved. In total, all participating members in both groups proactively responded to the 'Primary Object' (see page 23) with the crowd using 232 representations, and the experts using 81 representations. In response to the brief there was persistent activity from the crowd, in contrast to the limited and sporadic activity observed in the expert group that spanned the full 14-day time frame. Primarily this response confirmed that the set design task in this study was sufficient to catalyse activity in both groups.

The activity that arose revealed significant differences in the distribution of information and the abstraction employed in communicating that information. The difference in the way the representation was being used to present design information by the experts and the crowd infers that comparisons can be drawn based on the experts' vs novices' literature—as it is the crowd which contains novice participants. In the openly shared collective context of this study, the representation was found to be an integral component in the sharing of design-reasoning processes. These processes consisted of expressed intuition, trains of thought, inquiries, questions and arguments. Furthermore, the presence of the representation initiated collaborative responses which (were pertinent to) are a particular to collective systems. While individually not possessing the range of reasoning processes observed in the expert designer; it was under collective circumstances, and through the use of the representation, that abductive reasoning was observed and captured.

The differences revealed in the general analysis of Chapter 5 support Hypothesis 1 in this dissertation (Section 1.3). Furthermore, the observed differences in activity were sufficiently different enough in both groups to support the exploration of Hypothesis 2 (Section 1.3, and discussed across Sections 9.2, 9.3 and 9.4).

9.2 SHARED SEMIOTIC CHARACTERISTICS

Subject to Hypothesis 1, it was expected that the experts and crowd would have different approaches to generating and directing information for design purposes in the ODE. An analysis of the data which is presented in Chapters 6, 7 and 8, tests Hypothesis 2 (Section 1.3) and presents the differences in the

reliance on the representation to communicate design information with the ODE.

Within the limits of the method used in an openly shared web-based context, such as the ODE provided in this study, experts and a crowd alike made use of the representation to express design thinking. That is, when designing in an ODE such as the one established for this study, to a certain extent, the experts and the crowd members shared some commonalities in representational use. Emerging from the activity of the two groups were two shared patterns in activity: the representation supported the expression of reasoning processes, with varied informational outcomes in both groups; and, the accumulated generation of meaning-initiated interactions revealing movement within collective design activity in the ODE.

Both groups produced design-related information in a process which involved borrowing the qualities of icons to express index and symbol-related design content. The process of intuitively or intentionally borrowing existing features of iconic imagery to express abstract meaning indexically, such as ideas, is described by Peirce (CP 3.433) as a reasoning process he called abduction. Abduction is crucial for the creative process because it enables the individual to reason upon elements embedded within existing iconic imagery in order for them to be isolated and borrowed or combined to communicate new concepts. The abductive process of borrowing of qualities was a shared practice in both groups, but it is within each group's abductive processes that there were observable differences in the range of information and the levels of abstraction by which that information was conveyed. For the expert group there was a much higher level of abstraction within a narrow informational framework, in contrast to a much lower level of abstraction and a much wider informational framework in the crowd group. The difference in semiotic distributions and the levels of abstractness by which these informational values are conveyed suggests differences in the experts' vs. novices' thinking within the collective design context of this study.

The second characteristic to emerge was the presence of the semiotic transition itself. The transitions between Sg, Sd⁽¹⁾ and Sd⁽²⁾, in both groups, suggest that

within the collective conditions used in the experiment, there was an unmediated movement of design meaning. The crowd and the experts were using the image not only for generating, but independently reviewing, evaluating and eventually extending the original design-related content by adding more analogous meaning to it. Individually, members within the crowd in the ODE were capable of expressing design meaning through imagery. Furthermore, the existence of movement beyond the initial generation of design information implies that there is a capability for the crowd to engage in the development of an extended design dialogue in a collective setting such as an ODE, and this is reviewed in Chapter 8.

The presence of this initial activity was promising because the accumulating representational contributions vindicated the collective laboratory conditions. Moreover, the presence of activity centred on the representation was a significant finding because it implies that the crowd, as with the experts, used external images engendered with meaningful design-related information to express design meaning within the collective context. Each participant in both groups demonstrated a capacity for intuitively using icons to creatively build analogies and express ideas; this indicated that abductive processes were evident in both groups. In the crowd group, the individual contributions of imagery were prolific and consistently added to and interacted with. This was in contrast to the expert who traditionally does not design under collective conditions, which might explain the participatory differences between the crowd's consistent activity and the long period of inactivity in the expert group, until the last two days of the test period.

It is these two overarching characteristics, the abductive expression of design reasoning, and the movement of design information that emerges from the analysis of Chapter 6, and provides the theme for Sections 9.3 and 9.4 respectively.

9.3 CHARACTERISTICS OF INFORMATION WITHIN THE ODE

An analysis of the data presented over Chapter 7 corresponds to the testing of Hypothesis 2 (Section 1.3) and reveals the differences in the way the representation was used to convey design information. The participants in both

groups engendered design meaning into imagery by freely employing various characteristics borrowed from the embedded qualities of existing icons.

Mapping both of the groups to determine how they used the icon abductively to generate analogies indexically revealed that despite the presence of abductive reasoning in the ODE, the content of the abductive reasoning was unique to both groups. Since the abductive process is difficult to measure at best, this dissertation focuses on the outcomes of the differences in reasoning processes exhibited by the expert and crowd group. The types of reasoning exhibited are described according to the two characteristic aspects: expert top-down and novice bottom-up.

In the expert group, the content was far more abstract in that the images were often used to convey meaning that was visibly very far from the content of the image. For the experts, the information was of a much higher level of abstraction. Often the image in an expert's circle would be a pattern, a sketch or an image of a material with references to building skins. As such, the level of information generated in the experts' circles was of a much more analytical nature. For the experts, the autonomous exploration of the issues on a much wider conceptual and analytical scope was a defining characteristic of the how they used the representation to generate meaning throughout the entire experiment. In contrast to using imagery to generate informational schemas and explore subproblems (as observed in the crowd), the experts used imagery to complement a deeper, more explicit problem-decomposing strategy (Cross, 2004). In the ODE the experts engaged with the design task by using a mixture of qualities found in general iconic and symbolic representations to abstractly reflect components considered key to the design task. By extracting various qualities of imagery in seemingly vague and abstract ways, a deeper, more explicit problem-decomposing strategy became evident. This approach was less concerned with a final solution; instead the imagery was used to define the parameters of the problem (Cross, 2004). A much higher level of abstract indexical meaning was engendered in the imagery by decomposing the design problem and using iconic representations to infer analytical components. In design literature, this is regarded as being a predominantly top-down and breadth-first approach (Cross, 2004).

For the crowd, the images selected appeared to reflect not only their perception of the design task, but their considerations of a subproblem. This perceived visualisation was informal and in the ODE the contributions initially appeared arbitrary, random and unordered. This in part can be explained in the sense that it was 'ordinary', 'familiar' or 'constructed' in the absence of any formal code or set of design related rules (Bonollo, 2011). Importantly for the crowd, the combination of the icon and the ODE presented the opportunity to communicate very easily discernible information by analogously using immediately recognisable qualities of images. It emerged that each participant performed similarly according to this process—design meaning was isolated to their scope of design knowledge, understanding or insight into certain individual elements of the task. In this respect, in the crowd group, the representational use was governed by predominantly literal design meaning—literal because the images were often used to convey meaning in relatively close proximity to the content of the image (Wade, 1977). For example, the crowd participants inserted a collection of images into a circle that would cumulatively generalise certain categories of information such as environmental factors, technical considerations or schematic constructs (such as drawings, plans and elevations). For the crowd, each circle contained a body of images supporting knowledge that was predominantly concerned with exploring themed subsolutions. This type of bottom-up activity within design is often associated with novice activity and defined as the 'depth-first' approach when involved in solving design problems (Cross, 2004). For the crowd, the autonomous exploration of the subelements of the task, rather than the whole task itself, was a defining characteristic of their behaviour throughout the entire experiment.

9.4 CHARACTERISTICS OF MOVEMENT WITHIN THE ODE

An analysis of the data presented over Chapter 8 corresponds to the testing of Hypothesis 2 (Section 1.3) and reveals differences in the way the representation was used in the movement of design information. In both groups the presence of visual informational resources was sufficient to catalyse a number of types of interaction. The resulting interactions generated the addition of meaning to $Sd^{(1)}$ imagery, which generated the second $Sd^{(2)}$ context.

Combined, these indirect interactions produced the transitions that resulted in the captured movement of the design information within the ODE.

Expert designers traditionally do not design under collective conditions, which might explain the participatory differences between the crowd's consistent activity and the long period of inactivity in the expert group until the last two days. However, in both groups the over-time *movement* of design meaning occurred through indirect asynchronous interactions based on a particular image or existing text and not through synchronous collaborative efforts with other participants. This type of interaction is common to collective and web-based systems and is understood as stigmergic collaboration. Stigmergy is a method of communication whereby individuals communicate with one another by modifying their (or items in their) local environment (Elliot, 2006). This is highly characteristic of many types (if not all) of web-based communication in use today (Elliot, 2006).

Having generated the information (via the $Sg \rightarrow Sd^{(1)}$ transition), certain participants began to add new interpretations indexically for the sole purpose of contributing new informational variables to the existing design-related meaning of the image. The result of the interaction was a modification of the meaning via the iconic—indexical transitional relationship that associatively generated additional meaning to the original content. This movement did not occur through normal collaborative processes but by the incremental addition of 'small chunks' of information to existing imagery. In both groups, stigmergic activity was responsible for all movement of design meaning captured by the $Sd^{(1)} \rightarrow Sd^{(2)}$ transition. Overall, there was little difference between groups in terms of new information being generated based on existing $Sd^{(1)}$ representations and *Appending* and *Referencing* were two different approaches that informed an indirect type of collaboration within the ODE.

The implications of this are that the indirect *Appending* and *Referencing* activities might be types of collective stigmergic design activity. This implies that collective design activity can exist outside the currently mediated web-based crowdsourcing architectures when imagery is part of the equation. *Appending* and *Referencing* might also reflect a typical process of interacting with a design

problem when imagery is integral to the collective web-based context such as that provided by the ODE in this study. From this it might open up possibilities for current crowdsourcing, or any web-based design-related venture to investigate the provision of decentralised media rich platforms for the sole purpose of exploring the capture of collective reasoning processes that occur over time through stigmergic efforts. This would imply the need to develop far more complex systems than are currently available to accommodate and capture both the collective abductive reasoning activity and the resulting information effectively.

Despite the divergent differences in activity between the expert group and the crowd group, the results of the bottom-up activity in the crowd are revealed as significantly convergent with the top-down activity of the experts. The comparative analysis of the data in this study revealed that from the bottom-up processes of the crowd, a number of recognisable top-down design-related activities arose. In collective systems, it is the process of Stigmergy which leads to a complex 'higher order' emerging through the collective 'lower order' input based on the contributions of autonomous multiple agents. The concept of higher order phenomena arising following lower order Stigmergy is well described by emergence (Lewes, 1875). Stigmergy succinctly describes the indirect collaborative efforts of the participants in both groups of this study. And emergence describes the combined result of the lower order stigmergic efforts of the crowd, in comparison to the higher order efforts of the experts. It is these emergent top-down processes of the crowd that mimic certain elements of the top-down processes provided by the experts' data, which is one of the most significant findings of this study.

9.5 CONCLUSION

The aim of this study was to determine the role of the representation in a collective design context when the conditions were openly shared and web based. To achieve this aim two hypothesis were formed. The Hypothesis 1 was that the crowd would, in comparison with an expert benchmark group, exhibit observable differences in using the representation for communicating in the ODE in general. Subject to Hypothesis 1, in Hypothesis 2 it was expected that

the experts and crowd would have different approaches to generating and directing information for design purposes in the ODE.

For this dissertation it was important to ensure that the collective conditions were provided by the environment were consistent for both groups and those conditions were suitable for conducting a comparison between the groups. As with any digital environment there are inherent issues in how that environment might affect the type of design information, how it is generated and how it is shared. In adopting Lévy's (1997) ideological framework for collective intelligence - openness and decentralised freedom - the type of design information, how it was shared and the communication mode was always going to be determined solely by the groups based on their chosen activity.

Furthermore as no such current platforms yet exists that support or cater for openly collective design activity a significant first step would be to explore and develop the necessary tools that support collective design activity. This would in turn allow researchers the opportunity to identify the various modes of design communication that might also occur under certain collective conditions. The development of specific environments that allow the exploration of collective design would then enable research into both the process and the potential for extracting and capturing design related outcomes.

Overall, this study suggests that the role of the iconic representation in a shared collective environment is similar to that of the icon in a traditional design context. In design, the icon's chief ability is to facilitate the meaningful communication of associative and analogous reasoning. Associative and analogous process, or abduction, is not isolated and specific to design experts, but an arbitrary and unilateral human quality that anyone can utilise in order to generate meaning by using and combining symbolic and indexical qualities of existing imagery. During this study, both groups significantly used the iconic representation as a vehicle for generating and expressing design knowledge through indexical associative and analogous content. To this end, there were few differences. However, the analogous meaning was scalable to the intuition of the participant, revealing that there were different reasoning processes present in both groups. This confirmed that representation was used differently; supporting Hypotheses 1 in this study.

The reasoning produced in the expert group displayed a deeper level of conceptual information generation as it focused on using images for greater abstract meaning and a much narrower scope of design information. Individuals within the crowd similarly worked autonomously, again using the icon, but focused on expressing a knowledge specific to their scope of reasoning within the ODE.

However, in both groups the interactions that occurred were stigmergic, in that individuals interacted with the representational objects only, and not with each other. The activity of reasoning upon other participants' work in turn generated new information. The combined knowledge generated from the lower order, bottom-up stigmergic activity of the crowd contributed to producing activity and information that was greater than the sum of the information any one participant could have provided. Furthermore, the activity of the crowd echoed certain characteristics exhibited in the expert group, which was a higher order, top-down approach to generating design information.

For Hypothesis 2, it was expected that the experts and crowd would have different approaches to generating and directing information for design purposes in the ODE. The findings infer that the individual within the collective context, when engaged in creating something from nothing, utilises the representation for associative reasoning processes. In doing so, their reasoning becomes the creative contribution to a collective design activity that is characterised by its emergent properties. The similarities and differences in activity of the individuals within the ODE imply that whilst the representation was relied upon in both groups, it was relied upon to generate different types of information in uniquely different ways. This, in part, supports Hypotheses 2 in this study. study.

9.6 FURTHER IMPLICATIONS

The most pertinent implications that were recognised during the course of this study are presented here. The implications are reduced to three applicable categories ranging from collective design research, crowdsourcing to design implications.

Implications for collective design: The main contribution of this dissertation is that it enhances our understanding of collective design. Generally, design is an abductive process (Dorst, 2011). The results of this study suggest the lower level abductive patterns (patterns that shift between two types of activities—the generation of design knowledge and the abductive creative interaction) are reflected in the top-down processes of the experts' data. This implies that although the activities were slightly different between groups, the higher order emergence arising from the lower level activities of the crowd is worthy of further investigation with a view to potentially harnessing this phenomenon. The commonalities between higher order activities of the experts and the emergent design characteristics that arose from the crowd's lower order activities identified in this study, support the argument that, in terms of high level thinking, the crowd can produce similar higher order activity, albeit as an emergent, nonintentional process. These preliminary findings have implications for the development of applications which both support collective design activity and capture the resultant emergent activity.

Environments supporting collective design might provide many new possibilities. Architects and crowds combined have the potential to simultaneously combine lower order heuristic subproblem searches and information generation with higher order analytical activities. The emergent outcome, of course unpredictable, might be managed by a number of governing parameters (established by the primary object). One possible advantage might be that new informational values and prototypes may emerge in a much smaller timeframe. Producing alternatives through emergent processes is a fundamental activity in design. This suggests that the individual elements that produce emergent processes might be captured through the development of a new generative plug-in style interface that acts as a link between existing software and the crowd. The research and development of such applications presents many new possibilities for design.

Furthermore, to identify the meaning that was generated, it was necessary to rely on an expert group for benchmark data. One of the leading areas of research in design studies is the comparison between experts and novices. Regardless of approach, area of study, content or topic, the two groups are

identified as separate groups based on the perceived cognitive relationship to one another. However, the development of a new environment whereby the groups are combined would yield a better picture of collectivity in design.

Implications for crowdsourcing: The imposition of a process-based mechanism, such as the process-oriented design data collection seen in current crowdsourcing methodologies, is significantly top-down in two simultaneous contexts. Firstly, these mechanisms are centralised structures relying on modelled, stage-by-stage processes. By virtue of the absence of the support for decentralised systems, these structures cannot allow for autonomous indirect interaction. The process is also top-down in respect to the adjudication of the submitted design. At each stage of the modelled design process, expert designers arbitrate all submissions. This brings into the picture additional variables such as, but not limited to, personal prejudice and preference. Crowdsourcing depends on the judgement of experts in assessing significantly large volumes of novices' submissions. As such, crowdsourcing still manages to keep separate, on many levels, the very assets that produce successful collective intelligence; that is, the diversity of autonomous individuals in a decentralised system. Therefore, as Maher (2010) recognised, crowdsourcing cannot be described as collective design. However, if you combine experts with the crowd in an openly shared decentralised environment, then true collective diversity can exist. This is missing from current crowdsourcing structures.

Developing systems that can simultaneously allow the combined sharing of higher analytical process with lower order activity might present new opportunities to develop systems that can cope with this activity. This would enable a much deeper exploration into the potential benefits of emergent collective design activity in developed crowdsourcing systems. Indeed, the results of this study provide very early data regarding a concept Levy (1997) has already discussed:

A real time mechanism for direct democracy in cyberspace would allow participants to develop and refine shared problems on a continuous basis, introduce new questions, construct new arguments and formulate independent positions on a wide range of design topics (p. 65).

This research shows that open systems can support collective design activity, as those simulated in this study. The results showed that design activity was not characterised by individual activity, but arose as an emergent phenomena. The benefit to crowdsourcing might lie in the development of a system to support and capture this activity. Using specifically dedicated online design tools, a crowd member's contribution could play a significant role in the emerging process and ultimately, if captured, could have a relevant impact on the desired outcome set by the design task. Through qualitative observation of our experiment, the crowd appeared to use the iconic representations sourced from the Internet or generated by themselves. The advantage of this approach is that at every step the information generated was clearly readable by other participants.

The emergent characteristic of openly collective design in decentralised systems has never been identified before. Crowdsourcing is a centralised system that has an established history generating multiple outcomes. However, this system has remained unchanged since its inception and has yet to produce a replicable design. The characteristics of emergent collective design, such as those identified in this study, can be used to develop guidelines for the future development of ODEs. This would allow for the exploration of unique approaches to extracting collective design results from within crowdsourcing systems.

Implications for design research: By applying a semiotic approach to understanding the representations role in the flow of design information in an openly shared ODE, the research method applied in this study provided references for future design studies. These can be accounted in three main categories, all of which were developed during this research: the capture of a collective activity as involving the representation; the initial development of collectively shared open online design environment; and, a semiotically oriented mixed method of comparative analysis, in which the main patterns of emergent activity in the provided collective ODE were identified. By applying the adaptation and development of these research methods and tools to future design research, the behaviour in collectively oriented online design

environments can be further explored. Specific extensions of this research are discussed below.

Capturing of collective reasoning processes. Whilst individually not possessing the range of reasoning processes observed in the expert designer; it was under collective circumstances, and through the use of the representation, that the crowd produced higher order emergent design characteristics that were beyond the sum of its parts. The process of intuitively or intentionally borrowing existing features of iconic imagery to indexically express abstract meaning, such as design information, is described by Peirce (CP 3.433) as a reasoning process he termed as abduction. In contrast to induction and deduction, abduction is still relatively confined to the extensive body of research generated by the disciplines of philosophy and AI (Park 2015; Flach and Kakas 2000). Having produced an extensive body of literature in design cognition; a number of design researchers are now returning to the relatively obscure area of abduction. In that tradition this study captured, at a basic level, abductive reasoning processes occurring under collective conditions. The design activity captured in this study suggests that within collective systems it is the human intelligence that is the creative agent and although in its infancy, revealing that design activity does occur under such circumstances is worthy of future investigation. Furthermore because of its computational a digital nature, the development of collective mechanisms to capture abductive processes from these creative agents has implications for the field of AI. “One of the main goals in AI is to design a full architecture able to perform something like the three kinds of Peircean inference. One of the hardest tasks is, of course, to build an abductive engine” (Tohmé 2015). “The question to be raised by a logician in the Peircean tradition is how to accommodate the third type of inference” (Tohmé 2015). The implications of this study might extend the notion that rather than attempt to artificially model abduction, it might through certain collective mechanisms, be captured to form a hybrid AI component within current AI modelling systems.

9.7 FUTURE STUDIES

The current study has some limitations due to the research method and cost/time constraints. To address these limitations and optimise the findings, future studies should take into account the following issues. As with any study of this nature, there are many intricate subissues and the following recommendations are restricted to the most pressing at the time of publication.

- **Larger sample size.** The current research is based on four experts and 18 crowd members' design activity over a permanently open 14-day design sessions. While this is reasonable for doctoral research and never previously attempted, it is difficult to generalise these results to all expert designers or non-expert crowd members. However, the role of the representation in generating meaning, via semiotic patterns, has been identified in this study and future studies may lead to a more comprehensive understanding of the role of the representation in a collective design task. A larger sample size would help to refine and generalise the results of this study to a wider population.
- **Mixed-skill group sampling.** Collective design infers a shared undertaking in an open environment. In order to determine patterns in activity, this study reviewed and compared the activity of two isolated groups. Future studies might investigate the activity of a combined expert and novice group within the same online design space.
- **Specific ODE Development.** Future work in this area would benefit greatly from the establishment of a suite of web-based, collectively oriented, design collaboration environments. Future studies might produce ODEs which combine elements of open systems, such as decentralised structures, to provide the freedom for generation of collective intelligence. Such developments might complement the staged approach, such as those found in contemporary crowdsourcing systems which combine the organisational mechanics of traditional crowdsourcing systems, with a functionality that incorporates combined groups of experts and novices.

- **Outcome based results.** Future work might extend to exploring how design outcomes can be extracted from the collective activity that arises within an ODE.
- **Capturing collective design emergence.** In design, the typology of representations used plays a large role in the process and the development of design knowledge. We are far from looking at creative outcomes in terms of using CI and emergence to determine form, but the relationship between the typology of images, and the meaning they convey, is worth investigating. Future research might extend the ideas in this study by designing a system to capture data from future ODEs in a way in which it was possible to explore the generation of form, as dictated by both the information and behaviour, within a collective system.

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THE DESIGN CHALLENGE

We need a crowd to create and provide ideas, images and thoughts which contribute to the design of a contemporary home based on important issues facing the housing industry today - affordability and the environment.

We are looking for expressions of ideas that are daring, liveable and contemporary while remaining affordable and 'green'.

1) We want you to think about the home using a 'kit of parts' approach (modular design) where parts can later be interconnected.

2) We want you to do this in the 'Greenest' so your ideas can be realised with the least impact on the environment.

It is important to understand you are not expected to have all the answers - no one person knows everything - but everybody knows something.

GOOD LUCK - And most of all, enjoy!

**DON'T FORGET
TO
SAVE YOUR WORK.**

Appendix II: Ethics approval

HUMAN RESEARCH ETHICS COMMITTEE



Notification of Expedited Approval

To Chief Investigator or Project Supervisor:	Doctor Ning Gu
Cc Co-investigators / Research Students:	Mr Darin Phare Professor Anthony Williams
Re Protocol:	Investigating representational media in crowd oriented design: The shared process of modification in facilitating innovative crowd responses.
Date:	25-Jan-2013
Reference No:	H-2012-0433
Date of Initial Approval:	23-Jan-2013

Thank you for your **Response to Conditional Approval** submission to the Human Research Ethics Committee (HREC) seeking approval in relation to the above protocol.

Your submission was considered under **Expedited** review by the Chair/Deputy Chair.

I am pleased to advise that the decision on your submission is **Approved** effective **23-Jan-2013**.

For noting: Please ensure that any agreement with the design competition organisers regarding the use of their competition as part of your research, is obtained in writing and retained for your records.

In approving this protocol, the Human Research Ethics Committee (HREC) is of the opinion that the project complies with the provisions contained in the National Statement on Ethical Conduct in Human Research, 2007, and the requirements within this University relating to human research.

Approval will remain valid subject to the submission, and satisfactory assessment, of annual progress reports. *If the approval of an External HREC has been "noted" the approval period is as determined by that HREC.*

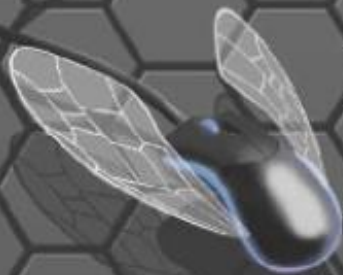
The full Committee will be asked to ratify this decision at its next scheduled meeting. A formal *Certificate of Approval* will be available upon request. Your approval number is **H-2012-0433**.

If the research requires the use of an Information Statement, ensure this number is inserted at the relevant point in the Complaints paragraph prior to distribution to potential participants You may then proceed with the research.

Appendix III: Recruitment posters



Do you have ideas and views?



The School of Architecture and Built Environment at the University of Newcastle is looking for volunteers to participate in a crowd based design research project.

Your participation will contribute toward a real design submission for an international web based design competition.

Want more of a say in our cities urban landscape? We live in cities and urban areas where design decisions are more often than not made on our behalf. This research requires the involvement of an online crowd to provide valuable data on the power of the crowd to solve real world design problems using the potential power and voice of collective intelligence to address design issues that affect us all.

Key Selection criteria:

- There is no specific inclusion criteria.
Remember ----- WE WANT AN ONLINE CROWD.

In recognition and appreciation for participation the top ten contributors will be provided with redeemable online vouchers to a movie of thier choice.



Complaints about this research?

This research has been approved by the University of Newcastle's Human Research Ethics Committee, Approval No H-2012-0433. Should you have concerns about your rights as a participant in this research, or have a complaint about the manner in which this research is conducted, it may be give to the researcher or if an independent person is preferred, to the Human Research Ethics Officer, Research Office, The Chancellery, The University of Newcastle, University Drive, Callaghan, NSW 2308, Australia. Telephone (02)49216333, or email Human-Ethics@newcastle.edu.au

School of Architecture and Built Environment
University of Newcastle, Australia
Contact: Darin
Phone: 0402 716 244
Email: darin.phare@newcastle.edu.au

Interested in how Collective Intelligence can benefit you?



The School of Architecture and Built Environment at the University of Newcastle is looking for six volunteer expert designers to participate in a research project.

Your participation will contribute toward a real Urban Design submission for an international competition.

This valuable experience will provide you with an understanding of the structures involved in implementing online crowd based participation in the design process. You will gain valuable knowledge and insight into how design can be applied in practice against the growing digital global context where design skills are increasingly becoming crowdsourced

- A tertiary qualification in architectural / engineering / industrial or similar design discipline.
- Minimum five years of professional design experience or five years of design studio teaching experience.
- Competency in practising and communicating design in an English-speaking environment.

In recognition and appreciation for your participation you will be provided a book voucher redeemable at participating vendors.



Complaints about this research?

This research has been approved by the University of Newcastle's Human Research Ethics Committee, Approval No H-2012-0435. Should you have concerns about your rights as a participant in this research, or have a complaint about the manner in which the research is conducted, it may be given to the researcher or if an independent person is preferred, to the Human Research Ethics Officer, Research Office, The Chancellery, The University of Newcastle, University Drive, Callaghan, NSW 2308, Australia. Telephone (02) 49216333, or email Human-Ethics@newcastle.edu.au

School of Architecture and Built Environment
University of Newcastle, Australia

Contact: Darin

Phone: 0402 716 244

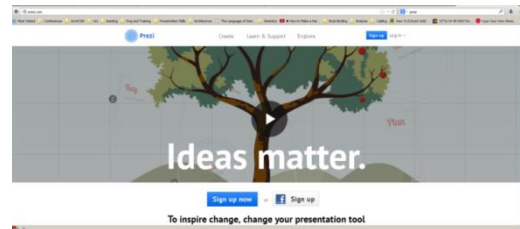
Email: darin.phare@newcastle.edu.au

Appendix IV: Experiment participation instructions

Welcome to the CDProject

Step 1.

Go to: www.prezi.com

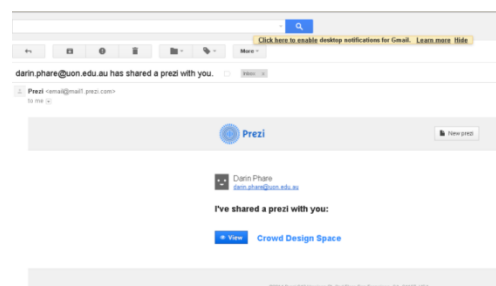


1. If you do not already have a Prezi account, register for Prezi with your email address (Choose public account), otherwise log into your Prezi account and proceed to **step 3**.
2. Please spend some time inside Prezi familiarising yourself with the Program.
3. That's it for step 1.

Step 2.

1. I will send everybody an email informing them of the start date (Wednesday 26th February).
2. On Wednesday 26th You will receive an email from Prezi saying:

Darin.phare@uon.edu.au has shared a Prezi with you.

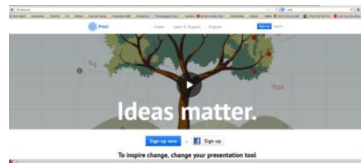


3. This is an automatic email informing you a Prezi has been shared with you

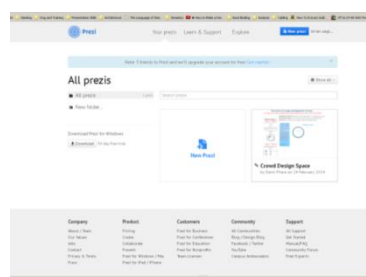
4. Please do not use this direct link, follow the steps below.

Step 3

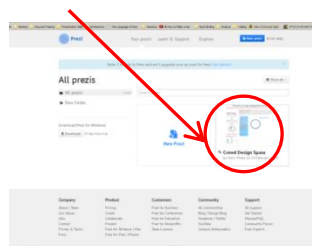
Simply Log onto Prezi



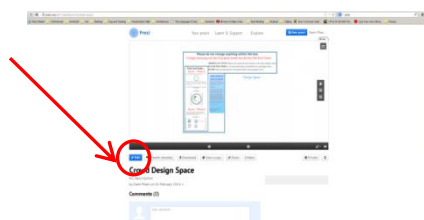
Your Prezi dashboard will have the Crowd Design Space added to it and look something like the below image.



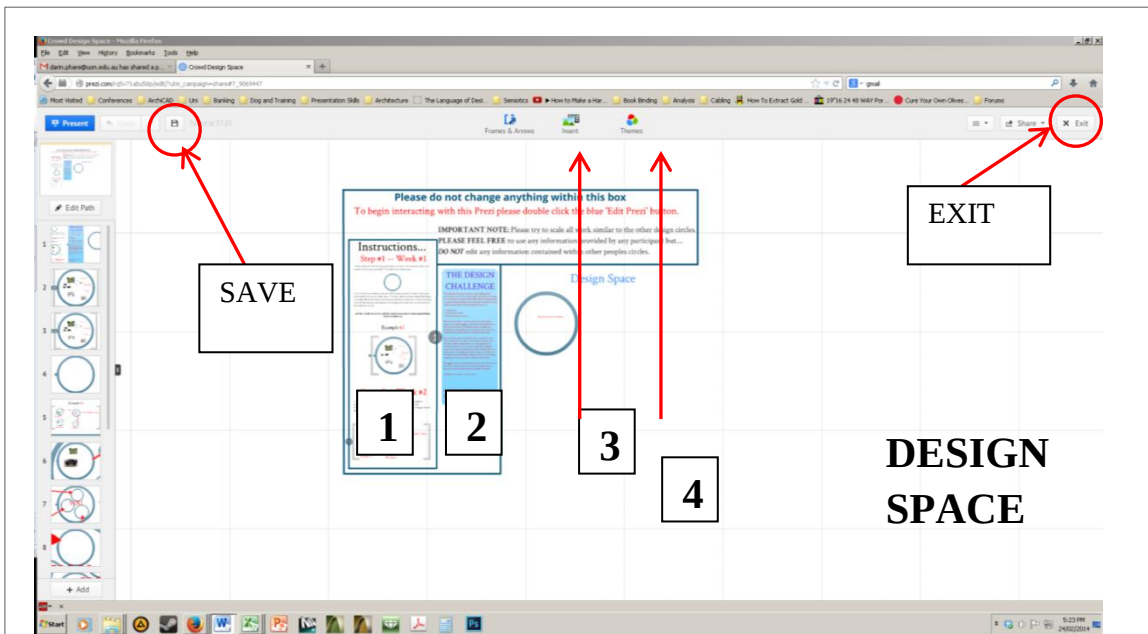
Click on the “Crowd Design Space”, this sometimes takes a while.



This will take you to the Crowd Design Space in Prezi. Click on the blue Edit button to enter the crowd design space, it make take a minute to load, so please be patient.



That's it; you're in the design space!!



Please spend some time familiarising yourself with

Prezi

Design Challenge.

Week one.

1. In box 1 (above) all you have to do is zoom in or out and **read the instructions** (use mouse wheel for this).
2. In box 2 (above) look at the three themes of the challenge.
3. Using the 'Frames and Arrows' function (shown by box 3) draw yourself a circle in the 'DESIGN SPACE'. This circle is a guide simply to help you manage the location of your activity.
4. Fill your circle with design ideas in relation to the challenge (using text or images via the 'Insert' function within Prezi (box 4).

Week two.

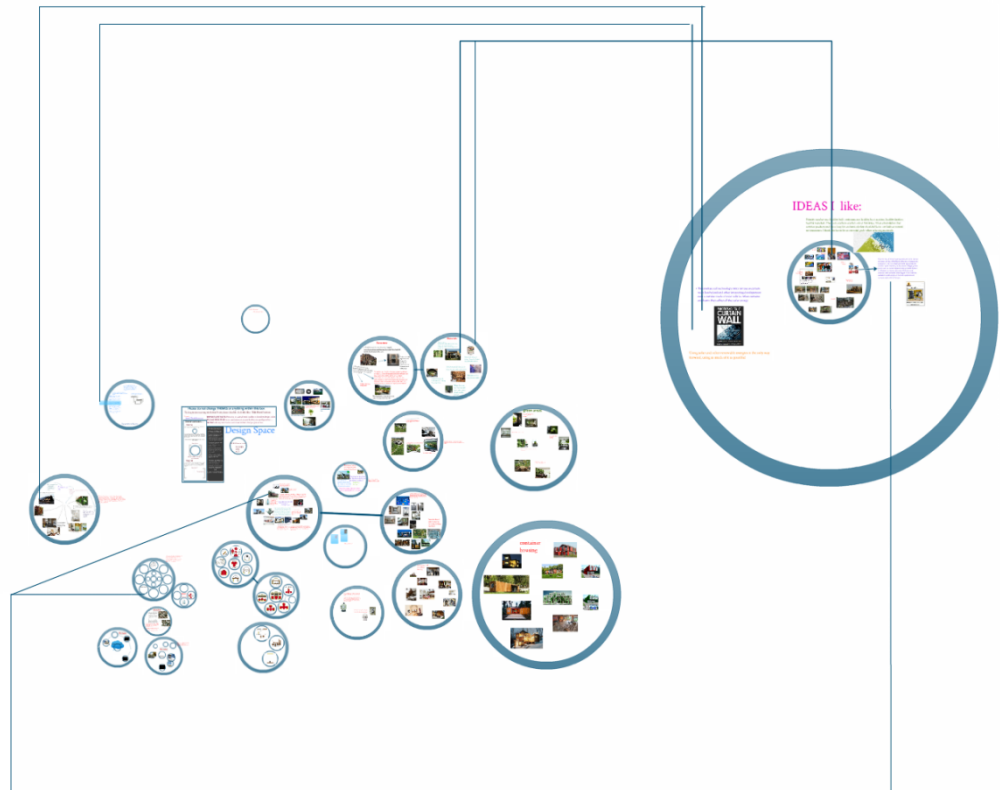
1. Same as week one, but in this week we start to look at other design work to see if it helps your ideas.

When your session is over just click 'SAVE' (top left) and then 'EXIT' (top right).

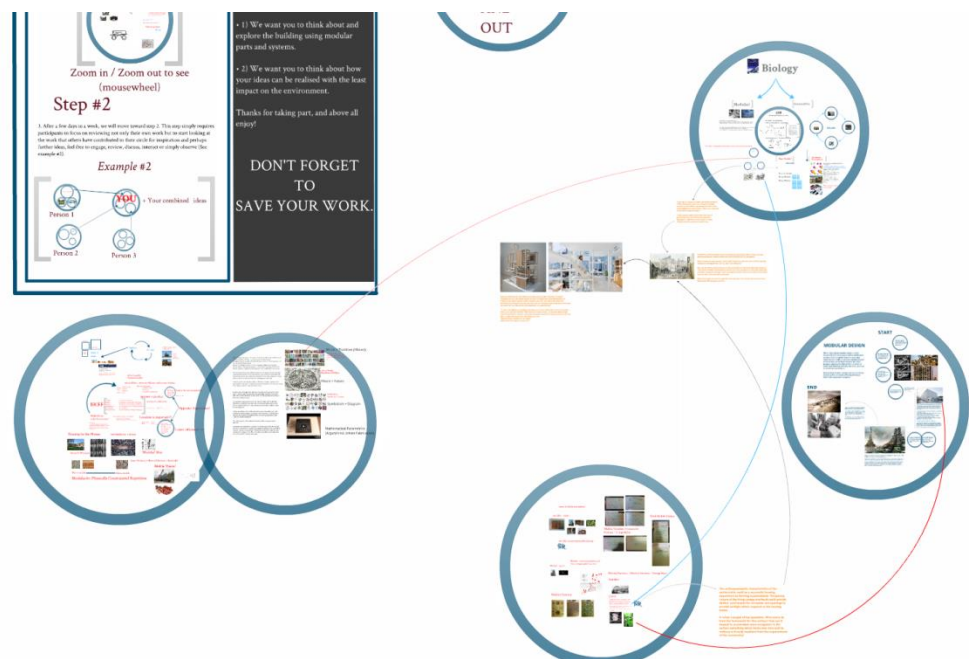
That's it!!!

Appendix V: Design activity results at day 14

CROWD



EXPERT



Appendix VI: XML transcripts

²⁸Crowd Transcript from XML

Finalised 17/04/2014. Created as Appendix – Original File in Dropbox/Analysis/Transcripts

Transcript of: Crowd - The Collective Design Experiment

- <![CDATA[Is either >Return key use or next line.

1 -200 = The chronological order of text input = Is matched to images in spread sheet

1xx.Rx = Number inserted chronologically and it is a (R)esponse = Interaction = Transitional Value 1per1.

- <![CDATA[

1. Select add frame from the drop down menu, choose circle and draw a large circle anywhere in the space provided. This will be your design space.

- <![CDATA[

2. You will use any media you choose (sketch, image and text) to show others your work within this circular design space. You may upload as many supporting images as you like. Please feel free to use any type of third party software to create any image you wish that you may feel supports your design intent, there are no restrictions on the media you can use.

- <![CDATA[

AFTER A FEW DAYS TO A WEEK YOUR SPACE MAY LOOK SOMETHING LIKE EXAMPLE #1

- <![CDATA[

3. After a few days to a week, we will move toward step 2. This step simply requires participants to focus on reviewing not only their own work but to start looking at the work that others have contributed in their circle for inspiration and perhaps further ideas, feel free to engage, review, discuss, interact or simply observe (See example #2).

- <![CDATA[

THE DESIGN CHALLENGE

Instructions...

We need a crowd to create and provide ideas, images and thoughts which contribute to the design of a contemporary home based on important issues facing the housing industry today - affordability and the environment.

- <![CDATA[

We are looking for expressions of ideas that are daring, liveable and contemporary while remaining affordable and 'green'.

- <![CDATA[

1) We want you to think about the home using a 'kit of parts' approach (modular design) where parts can later be interconnected.

²⁸ In the interest of maintaining fidelity the presented transcript is provided in its original format. It includes the original spelling and grammar errors as provided by the participants.

- <![CDATA[

2) We want you to do this in the 'Greenest' so your ideas can be realised with the least impact on the environment.

- <![CDATA[

It is important to understand you are not expected to have all the answers - no one person knows everything - but everybody knows something.

- <![CDATA[

GOOD LUCK - And most of all, enjoy!

- <![CDATA[

TIME IS THE ESSENCE

- <![CDATA[

omg- an idea

- <![CDATA[

+ Your combined ideas

- <![CDATA[

To begin interacting with this Prezi please double click the blue 'Edit Prezi' button.

- <![CDATA[

Please do not change THEMES or anything within this box

- <![CDATA[

Step #2

- <![CDATA[

Example

- <![CDATA[

#1

- <![CDATA[

Example

#2

- <![CDATA[

EXAMPLE DESIGN CIRCLE

- <![CDATA[

ZOOM IN AND OUT

- <![CDATA[

Zoom in / Zoom out to see

- <![CDATA[

(mousewheel)

- <![CDATA[

DON'T FORGET TO SAVE YOUR WORK.

- <![CDATA[-----

1. I was thinking that if a water tank was on a roof really thin and flat, but largish, and then fed down from that into a tank under the house, the water in the roof would be heated by the sun and could be used for showers (no other heating necessary) and the water under the house would become nice and cool for other purposes?
2. Could you not also build different rooms in different shipping containers? So like a kitchen in one container. A bedroom in another. And then you can just mix and match them together depending on what customer wants. The customer says "I'll take that kitchen, and that bedroom, and that bathroom" and you just have the containers delivered to their property and put together on the spot.
3. Garages purpose built for electric cars
4. Submarine generators - a way to store massive amounts of electricity onsite without needing to be on the grid.
5. What do people want? I'd be happy with simple on the outside and beautiful on the inside.
6. Molding

- <![CDATA[

7. Dome house
- <![CDATA[
8. DIY home for less than \$3500
- <![CDATA[
9. Pushing up/prefab slab
- <![CDATA[
10. My house printer
- <![CDATA[
11. ScREW footings
- <![CDATA[
12. STARTING UNDERSTAND THIS
- <![CDATA[
13. R1. Amusing idea for printing a house, is it really going to work. Time between layers, and it cannot stop; each layer must be linked to the previous layer. How do you link the lintel, you need mold
- <![CDATA[
- A
- <![CDATA[
- B
- <![CDATA[
14. Question to Darin: Can you sketch in here?
I wanted to draw something.
- <![CDATA[
15. I can't figure out how to draw this idea so I'll have to put it in words. I was thinking about the word 'modular', and it made me think of training modules - a different 'module' for each training need. So in terms of a house, each room could be a 'module' that serves each individual's needs. They could be made so that the rooms just 'click' into each other and lock together. And then, like a car, you could trade in 'modules' back to the dealer for a trade-in price when you want to upgrade a room. So say the designer released a new 'bathroom' module that you loved, you could trade in your old bathroom and have it taken away, and then just have your new bathroom locked onto the house in it's place. The seller could reuse the parts of the traded in bathroom or just sell it as a second-hand bathroom module to the next person. This way, materials could be re-used over and over again, and people don't have to move location when they get bored of their current home, they can just trade parts of it in for a new idea or to keep up with the Joneses or when their tastes change. People could go modern in one room, Victorian in another, all different types of design depending on taste. A person could even have a different era of design in every room of their house if they wanted to. Interior designers would have a field day.
- <![CDATA[
16. R2 Excellent Q. Sadly no not in Prezi
The only real alternative is to draw
it on paper, scan it and upload the scan
- <![CDATA[
17. Roof top gardens to encourage bees and butterflies/pollination.
- <![CDATA[
18. Solar panels to produce electricity for the home and possibly sell back extra power.
- <![CDATA[
19. Under floor heating.
- <![CDATA[
20. Flat packed rooms, that can be inter locked/stacked, bit like hamster cages
- <![CDATA[
21. Vertical fans advantage is to less parts, the extra power from the winglet and always face the wind
- <![CDATA[
22. Horizontal fan needs to face the wind to work, so if the winds adjust, there is a delay in the supply of power
- <![CDATA[
23. The idea of cooling a room and gardening at the same time

- <![CDATA[
- 24. The first control of the environment, it is static parts of of the house
- <![CDATA[
- 25. Wind mill without mechanics
- <![CDATA[
- 26. If you could construct a material that was recyclable and strong enough you could build a house using uniform sized panels. If it was able to be cut using hand and power tools then the panels can be supplied in one size, cut to suit, and then off cuts can be recycled back. Door and windows could be cut size on site.
- <![CDATA[
- 27. The panels could be used for flooring as well, and services can easily be installed if ground floor is made using joists.
- <![CDATA[
- 28. Cross section
- <![CDATA[
- 29. actually. these stakes should probably go right into the earth beneath..
- <![CDATA[
- 30. R3.[RP] I think this is a great idea!
- <![CDATA[
- 31. R4. Thanks Rob, yeah the more I think about it the more I like it, because we spend so much money on renovating all the time when we want to upgrade, update etc. Why not just completely swap out a room for another - that money is well spent because what you get can include a completely different shape of space as well as a different interior design, and your old room can be recycled. Pp.
- <![CDATA[
- 32. R5 - I like these ideas - and if you were to have interlocked rooms that could be changed out, you could have a static infrastructure that included things like this so that the infrastructure stays behind when the rooms move, keeping it ecological.
- <![CDATA[
- 33. Another question to Darin: I have run out of space in my circle. Am I allowed to start another one?
- <![CDATA[
- 34. R6 A: Great Q on the circle space! Don't select anything - press and hold the 'Alt key' then while holding it down select the frame. Now you can now resize the frame and the contents should stay the original size. Feel free to start another circle if you like, just connect them with a blue line or something or an arrow, just so we know they both belong to you :) Have added example above. Thanks.
- <![CDATA[
- 35. Recycle abundant waste materials which don't readily break down in landfill and/or materials which can't be easily dumped like shipping containers for use in construction.
- <![CDATA[
- 36. Concept:
- <![CDATA[
- 37. Bottles:
- <![CDATA[
- 38. Cardboard:
- <![CDATA[
- 39. Pallets:
- <![CDATA[
- 40. Plastic Bags:
- <![CDATA[
- 41. Shipping Containers:
- <![CDATA[
- 42. Styrofoam:
- <![CDATA[
- 43. Tyres:
- <![CDATA[
- 44. Maybe clay/mud rather than concrete?

- <![CDATA[
- 45. Thinking about orientation of homes:
- <![CDATA[
- 46. Just stacking them doesn't really promote a desirable living space. (IMO)
- <![CDATA[
- 47. You just end up with a tower block scenario.
- <![CDATA[
- 48. If using modular pods they can be arranged in a grid.
- <![CDATA[
- 49. With a central garden/communal area...
- <![CDATA[
- 50. Pattern can be repeated to create larger communities. Each block of 9 units creates one dwelling. Mix and match individual units to create unique living spaces.
- <![CDATA[
- 51. A hive like community could be created.
- <![CDATA[
- 52. Thought #1.
- <![CDATA[
- 53. What modules make up a house?
- 54. - Somewhere to sleep
- 55. - Somewhere to eat
- 56. - Somewhere to bathe
- 57. - Somewhere to read/sit
- 58. - Storage
- <![CDATA[
- 59. Thought #3.
- <![CDATA[
- 60. How do we make these modules Environmentally friendly?
- 61. - Recycled water
- 62. - Solar energy
- 63. - Rain water
- <![CDATA[
- 64. Thought #2.
- <![CDATA[
- 65. What do we need to live comfortably?
- 66. - Food
- 67. - Water
- 68. - Electricity
- <![CDATA[
- 69. Vertical gardens using recycled grey water or collected rain water. Vertical structure allows for smarter use of space.
- <![CDATA[
- 70. Solar panel roofing for electricity and hot water
- <![CDATA[
- 71. Water tank to collect rain
- <![CDATA[
- 72. Clever storage solutions to incorporate kitchen, living area and laundry and to minimise heating & cooling costs
- <![CDATA[
- 73. Solutions.
- <![CDATA[
- 74. Somewhere to sleep
- <![CDATA[
- 75. Somewhere to bathe
- <![CDATA[
- 76. Thought #4.
- 77. What materials to build with to ensure environmentally friendly:
- 78. - Newspaper/ cardboard insulation

79. - Recycled timber & bricks
80. - Mud walls
81. - Bamboo
- <![CDATA[
82. This is the "building" from the Homebase advert in the uk-stacking containers.
- <![CDATA[
83. Found this on teh interwebs.
- <![CDATA[
84. Interesting site on it's own (strawbale.com) but also gives dimensions to work with...
- <![CDATA[
85. living space
86. bedroom
87. bathroom
88. kitchen
- <![CDATA[
89. Is this going to need extra support here?
Maybe I should consider tunnels between spheres?
- <![CDATA[
90. Standard 36' door frames would work
- <![CDATA[
91. extensive use of glass to encourage natural light
- <![CDATA[
92. the ultimate bathroom
- <![CDATA[
93. natural insulation
- <![CDATA[
- <![CDATA[
94. From this
- <![CDATA[
95. To this
- <![CDATA[
96. I would love to harness light and warmth from the sun and refract it to any place I like in my
underground home.
- <![CDATA[
97. If living underground could be made not only functional but homely
- <![CDATA[
<https://TheCDProject.net>
- <![CDATA[
Visit us at:
- <![CDATA[
98. Turning household food waste into energy via composting
- <![CDATA[
99. 2. Unused and derelict office spaces/warehouses to be converted to create affordable and
attractive city living spaces
- <![CDATA[
100. 1. Prefab homes for mass housing - <http://www.theguardian.com/housing-network/2013/apr/04/prefab-housing-benefits-costs>
- <![CDATA[
101. Bamboo flooring.
<![CDATA[
102. Reason - Environmentally friendly. Takes approx. 4-6 years to replenish in comparison to
hardwoods taking around 50-100 years.
- <![CDATA[
103. So I'm thinking. Modular. Lots of ideas about modular. L-shaped modular pods for
building. Easily linked, but providing a more interesting internal space. Windcells, windbelts,
windcell panels. All modular, ideal (from what I can gather) for rural use. And cheap!
http://www.humdingerwind.com/#/wi_overview/
- <![CDATA[

102. Grids of micro-solar and micro-windcell panels combined to provide all internal lighting, heating and hot water.
- <![CDATA[
103. The one they call Baldrick
- <![CDATA[
104. www.zerohouse.net
- <![CDATA[
105. Prefabricated automated homes.
- <![CDATA[
106. Transported to site and arranged in communities.
- <![CDATA[
107. Need to investigate sourcing of automation to reduce cost.
- <![CDATA[
108. Need to investigate fabrication and design of modules.
- <![CDATA[
109. Culturally appropriate
<![CDATA[
110. Transportable
- <![CDATA[
111. Healthy and affordable heat
- <![CDATA[
112. Repairable
- <![CDATA[
113. Consideration of human scale
- <![CDATA[
114. Healthabitat Prefabricated wet areas
- <![CDATA[
115. Ingenuity and use of available resources
- <![CDATA[
116. Traditional knowledge and skills
- <![CDATA[
117. extendable
- <![CDATA[
118. appropriate for the landscape
- <![CDATA[
119. Decorated using eco paints - better for health and the environment
- <![CDATA[
120. Structure
- <![CDATA[
121. Materials
- <![CDATA[
122. Parking in highly populated areas reduced by warehouse building turned into apartment with garage
- <![CDATA[
123. Rooftop garden - promote green area in urban development
- <![CDATA[
124. Mud plaster for any interior walls
- <![CDATA[
125. Water butts on roof to save and store rain water which can be reused
- <![CDATA[
126. "Somewhat surprisingly, old houses can be more difficult to renovate, due to the potential for hidden problems with pipes and electrical wiring, which are not always immediately obvious to the naked eye. Most former industrial spaces avoid such problems since the pipes and wiring are often on the actual surfaces of the wall. This makes them easy to remove and equally easy to replace."
- <![CDATA[
127. Ecological payback in a property
- <![CDATA[

128. Utilise materials already in place to cut costs and recycle
- <![CDATA[
129. R7 This idea of gardens got me thinking about having communal gardens that a community of dwellings can access, so a whole bunch of people don't have to go buying vegetables - everyone tends the gardens, and everyone reaps the gardens. P.
- <![CDATA[
130. R8 I really like this idea! My idea was to build room modules out of shipping containers, but I'd love to know from more building savvy people how you could use these other materials to build houses with? I know you can build like mud huts and houses with straw bales etc. but how cool would it be to be able to build structures with recycled plastics or tyres?? Any ideas anyone?
- <![CDATA[
131. R9 - Hey, as per above on someone else's ideas where I mentioned you could have communal veggie gardens for a bunch of dwellings to share, perhaps there could be like a windmill plot that a bunch of communal dwellings could also share, so you could harvest the electricity for a whole community, rather than just one house?
- <![CDATA[
132. R10 - Actually there are some really sweet underground dwellings at Lightning Ridge. Good idea because they're cool in summer and warm in winter
- <![CDATA[
133. R11 - Hey yeah, I'm in agreement that communities can share resources, like gardens and harvest of other resources from water tanks, solar power, and windmills etc.
- <![CDATA[
134. Modules could be designed using shipping containers to create the outer structure of houses while internal walls could be constructed using laminated cardboard, blocks made out of fused plastic bags or bottles set in concrete. Tyres could also be utilised for the structure using rammed earth construction and then rendered with mud etc. Modules made from pallets could work as well given their standardised sizing.
- <![CDATA[
135. Shipping Containers:
- <![CDATA[
136. Components could be dropped on site fully fitted out with power and water services.
- <![CDATA[
137. Designs are not limited to the dimensions of individual containers as they can be stacked and hacked to create open internal spaces however the spaces created are somewhat limited to the box-like shapes.
- <![CDATA[
138. Tyres:
- <![CDATA[
139. Pallets:
- <![CDATA[
140. The benefit of using tyres is they can create any shape imaginable including but not limited to circles, rectangles and turtles.
- <![CDATA[
141. Despite being square, pallets can create both box-like shapes as well as curved structures and can also be broken down for use as cladding.
- <![CDATA[
142. Bathrooms that look out on green areas, bringing the outside in, for relaxation.
- <![CDATA[
143. rooms surrounding indoor green areas
- <![CDATA[
144. Greening up of walls and building exteriors to soften harsh exteriors
- <![CDATA[
145. creating areas of garden within living environment

- <![CDATA[
- 146. making the most of outdoor areas
- with a garden "feel" about them
- <![CDATA[
- 147. green areas
- <![CDATA[
- 148. So my main idea, using all nutrition (food waste) and put the waste in to the local area; by local, my house and local area.....
- <![CDATA[
- <![CDATA[
- 149. The same idea should be done with water, as I draw house plans I always look at water and in the city it is considered a waste: Gray or black water can be used in a private land.
- <![CDATA[
- 150. Water stored under a house works as a thermal blanket (or a thermal mass), it maintains an average temp...how can we use that? Putting the gray water under the house
- <![CDATA[
- B
- <![CDATA[
- B
- <![CDATA[
- 151. In the local area/(Pic 1), that I know quite well, is that soil is full of clay and its hard to grow anything and any water just goes to nothing. It has almost no nutrites, yet food and water waste could be used to improve the soil and producing power on a small scale.
- <![CDATA[
- 152. These gaps can be found within a city, parks, roofs etc. (in Canberra it was designed by Burley Griffin i think).
- <![CDATA[
- 153. All gray water should go to the local areas, (Pic 2) but not sure how to deal with storm water thou.
- <![CDATA[
- 154. Conclusion:
- <![CDATA[
- 155. As well as using waste products for building components the homes need to be energy efficient so as not to create a drain on non-renewable resources. Use of vertical axis wind generators such as the ones
- Brendan - suggested would be preferable over Photovoltaics due to the high embodied energy of the latter.
- <![CDATA[
- 156. The best design would also include a greenhouse for food production to reduce reliance on produce requiring transport over large distances as well as water reuse to decrease/prevent the need for desalination plants in the future.
- <![CDATA[
- 157. Interconnecting L-Shaped modules would make for a more interesting internal space, and still allow for more conventional living areas.
- <![CDATA[
- 158. Possibly off-topic, but has anyone come up with an effective way of
- storing - electricity generated with green methods, e.g. solar, wind, etc.?
- <![CDATA[
- 159. Are there any crossover materials that could be used within construction that not only harness the energy but store it for later release? Or at least one or the either, i.e. harness or store?
- <![CDATA[
- 160. A previous idea on here somewhere mentioned using transparent solar panels - effectively solar panels used as windows. There HAS to be a way reliably storing unused energy so as to be as efficient as possible.
- <![CDATA[
- 161. Organic batteries? Ok, drifting totally off now, but if you can run a clock from a potato or an orange, the power source (potato, orange) clearly has stored power. Can that be reversed,

- e.g. some kind of concentrated (liquid?) mass that can store electricity? I dunno. dreaming. It might trigger an idea in someone though. Any chemistry students reading this?
- <![CDATA[
162. Found this: <http://now.tufts.edu/articles/how-can-we-effectively-store-solar-energy> - somebody do it on a commercial scale, then we'll be sorted.
- <![CDATA[
163. Photovoltaic cell technology exists for use as curtain walls (see below) and other interesting developments such as curtains made of solar cells i.e. when curtains are drawn they collect all that solar energy
- <![CDATA[
164. IDEAS I like:
- <![CDATA[
165. I like the idea of using shipping containers i.e. for disaster assistance and for rebuilding in urban areas of megacities. Containers could be prefabricated with appropriate fit-outs for rooms - kitchens, bathrooms etc. Shipping from port to port, to coastal regions or only accessible by boat i.e. disasters on islands, such as the Phillipines and resources and food needs to be shipped. I also think that containers could carry food, medical equipment and resources such as Solar Suitcase.
- <![CDATA[
- 166.R12 - Using solar and other renewable energies is the only way forward, using as much of it as possible!
- <![CDATA[
167. Priority number one: healthy built environments: healthy heat creation, healthy finishes, healthy materials. The book cradle to cradle looks at this issue. It has a foundation that certifies products and has a long list of chemicals that shouldn't be in our built or natural environments. I think this has to be an essential guide when selecting materials.
- <![CDATA[
168. Saw this on Facebook the other day, thought it was so cool! Imagine having rooms in your house that were like this, where you could look up at the sky whilst in bed, or in the bath? It would obviously be completely naturally lit during the day, and moonlit by night!
- <![CDATA[
169. I really like that you can close this one if you want
- <![CDATA[
- 170.Now the idea of glass houses has me titillated! Glass modules!
- <![CDATA[
- 171.making use of old churches for housing
- <![CDATA[
172. 1.Too much garbage in the red waste bin, Kitchens can - be designed to efficiently collect food and veg waste for mulch.
- <![CDATA[
173. 2.New houses-have ways that they collect the grey water
I think it should be expanded to collect pool backwashing.-----At the moment it goes straight into sewer and is better quality than grey water. It should go straight into grey water tank storage.
- <![CDATA[
174. container housing
- <![CDATA[
175. 3.Houses should have plenty of light - therefore - more windows to provide natural light but they need to be shaded to prevent heat penetration.
- <![CDATA[
176. to be built to make you feel like your on a tropical island all year round
- <![CDATA[
177. Animal grazing above your home
- <![CDATA[
178. With the usual luxuries
- <![CDATA[
179. Wall size plasmas providing natural vistas
- <![CDATA[

180. Fish pond for the perfect zen

- <![CDATA[

181. M.

- <![CDATA[

182. House Printer

- <![CDATA[

183. B

- <![CDATA[

184. Vertical Axis - Wind Generator

- <![CDATA[

185. Garden Ventilation System

- <![CDATA[

186. 2

- <![CDATA[

187. 6

- <![CDATA[

188. Inflatable Formwork

- <![CDATA[

189. Vertical Garden

- <![CDATA[

190. House Printer

- <![CDATA[

191. Ideas I - (besides my own of course)- Like

- <![CDATA[

192. R13 - Absolutely! you see community gardens in cities all the time but they can take up large units of space. If you can have a vertical garden which is part of the structure, and design, and also that can harness the rain, wind etc. that would be awesome...

- <![CDATA[

193. M. (I wanted to add extra photos but Prezi won't let me)

- <![CDATA[

194. R14 - Yeah! check this out: <http://inhabitat.com/solar-green-revolution-pavilion-made-from-recycled-plastic-bottles-launches-in-philippines/>

- <![CDATA[

195. R15 - M.A really cool example for sustainability is a cafe in Melbourne called Silo by Joost.

There's a pop up in Sydney and also a permanent one in Perth. -

The idea is everything from the building materials to what is put on your plate is completely sustainable, there is no rubbish!! - All food is sourced locally and all food and coffee scraps are returned to the local farmers to be used as fertilizer. Everything else is recycled. - This idea could be applied to modular living.

- <![CDATA[

A

- <![CDATA[

B

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P
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Q
- <![CDATA[
R

²⁹Expert Transcript from XML

Finalised 17/04/2014. Created as Appendix – Original File in Dropbox/Analysis/Transcripts

Transcript of: Expert - The Collective Design Experiment

- <![CDATA[Is either >Return key use or next line.
1 -200 = The chronological order of text input = Is matched to images in spread sheet
1xx.Rx = Number inserted chronologically and it is a (R)esponse = Interaction = Transitional Value
1per1.

- <![CDATA[
1 Biology
- <![CDATA[
2 Life cycle?
- <![CDATA[
3 Fuctioning
- <![CDATA[
4 growing
- <![CDATA[
5 structuring
- <![CDATA[
6 clustering
- <![CDATA[
7 Modular!
- <![CDATA[
8 BRIEF
- <![CDATA[
9 Liveable
- <![CDATA[
10 Modular
- <![CDATA[
11 'Daring'
- <![CDATA[
12 Contemporary
- <![CDATA[
13 Environment
- <![CDATA[
14 Housing Industry
- <![CDATA[
15 Comfort /Convenience
16 Standardised / Repeatable / Modifiable
17 'Daring'? Technical / Visual / ETHICAL?
18 As 'Architecture' or re Occupant Lifestyle?
19 Macro vs Micro

²⁹ In the interest of maintaining fidelity the presented transcript is provided in its original format. It includes the original spelling and grammar errors as provided by the participants.

20 Social / Technical / Political / Financial
 - <![CDATA[
 21 climate change
 22 land-use
 23 pollution
 24 food
 - <![CDATA[
 25 energy
 26 water
 27 disaster
 - <![CDATA[
 28 process vs product
 29 embodied energy
 30 technology
 31 Automated manufacturing
 - <![CDATA[
 32 "BENEFICIAL
 33 to the Environment"
 34 clarify 'benefit' ?
 35 1. Actual holistic improvement to micro / macro compared to not building / existing in the first place ?
 36 2. Better than standard practice? Where? Aussie McMansions = Easy to beat / Amazonian tribal huts = near impossible
 - <![CDATA[
 37 no perfect solution for all locations and climates
 - <![CDATA[
 38 sustainability = resource efficiency and socioeconomics
 - <![CDATA[
 39 possibly mitigated by modularisation?
 - <![CDATA[
 40 e.g. Different components to suit: Location / Occupant /
 <![CDATA[
 41 Mass production
 42 -Efficient Production
 43 -Low cost if high volume
 44 -High Quality (possible)
 45 -Efficiency of materials
 46 -higher tech possible
 47 -spare components
 - <![CDATA[
 48 high cost vs low income
 - <![CDATA[
 49 Acceptance by society?:
 - <![CDATA[
 50 US / Oz vs Singapore / Denmark
 - <![CDATA[
 51 Location is important!!!
 - <![CDATA[
 52 Latitude
 53 Altitude
 54 Distance from Sea
 55 Weather / Climate
 56 Lifestyle
 <![CDATA[
 57 local materials
 58 lower embodied energy
 59 local skills
 60 local vernacular (style)

61 local employment
 62 local economy
 63 sustains cultural diversity
 64 'Opposite' Approaches?
 - <![CDATA[
 65 Lack of Social sustainability?
 - <![CDATA[
 66 High Tech vs Low Tech?
 - <![CDATA[
 67 money vs community
 - <![CDATA[
 68 national equality
 69 global equality
 - <![CDATA[
 70 Lower 'efficiency' ???
 - <![CDATA[
 71 A modular system means pre-fabricated stuffs.
 72 In terms of construction cost, the modules probably relate to mass-products, standards.
 73 Who knows all the various modules without reference manuals? How to cover them?
 74 A modular system can be developed to an universal stuff, which suits for a variety of designs.
 75 The module probably comes from our basic measurement, hand, foot, etc.
 - <![CDATA[
 76 Can the new module, e.g. a cube 30 x 30, include a structural and convenient function?
 - <![CDATA[
 77 VS
 - <![CDATA[
 78 Let's make a new modular system that cover various housing functions.
 - <![CDATA[
 79 New
 80 Modular System
 81 for architecture and housing
 82 Form
 83 Lego
 84 Function
 85 Honeycomb
 86 Structure
 87 Housing
 88 Wall
 89 Slab
 90 Beam
 91 Column
 92 Roof
 93 Sleeping
 94 Eating
 95 Cooking
 96 Washing
 97 Bath & shower
 98 Study
 99 Entertaining
 100 A
 - <![CDATA[
 101 B
 - <![CDATA[
 102 some modular precedents
 - <![CDATA[
 103 modular is not necessarily discrete
 - <![CDATA[
 104 MODULAR DESIGN

105 When I think about modular design it a very structured set of ideas or parameters which when scattered or in a singular state are seemingly limited in their ability to perform anything outside of that of their proscribed attribute, but when grouped, organised or aligned with a number of others with differing attributes than the result can be an infinite combination.

- <![CDATA[

106 Most of these modular designs require a structure of sorts to link or bind the differing attributes. What is this structure? Examples?

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107 IS IT AN INTERNAL STRUCTURE WHICH BINDS THEM OR IS IT AN EXTERNAL 'SKIN' WHICH HOLDS THEM TOGETHER?

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108 ARE THE FAVELAS IN RIO DE JANEIRO AN EXAMPLE OF MODULAR HOUSING? IS THE CONCEPT OF THE SHANTY TOWN A VALID EXAMPLE? ARE THEY SINGULAR OR APART OF A GREATER WHOLE?

109 WHAT ABOUT IF EACH OF THESE STRUCTURES WERE STACKED INTO A TOWER LIKE THE TOWER OF DAVID? DOES THIS MAKE THEM MORE CONNECTED? OR MORE INDIVIDUALISED?

110 ARE THERE EXISTING CONSTRAINTS WITHIN NATURE THAT CAN FORM THE STRUCTURE FOR THIS COLLECTIVE HOUSING PROJECT?

111 EXISTING BUILDINGS/TOPOGRAPHY?

112 LETS EXPLORE THAT FURTHER

113 BOTH IN THE THEORETICAL &

114 PHYSICAL SENSE

115 HERE IS AN EXAMPLE OF AN INDIVIDUAL HOUSE BY SO-IL ARCHITECTS. FOR MOST PART IT IS QUITE A PAIRED BACK AND SIMPLE BUILDING. THERE IS AN OUTER SKIN WHICH IS MADE UP OF NETTING AND AN INTERNAL 'STRUCTURAL' BOX IN WHICH THE OCCUPANTS LIVE. THE THING THAT INTERESTS ME ABOUT THIS SETUP IS THE SPACE BETWEEN THE BOX AND THE NETTING.

116 1. THE STAIR WHICH WRAPS UP THE SIDE OF THE BUILDING IS IT INTERNAL OR EXTERNAL? OR BOTH?

117 2. DOES IT ONLY PERFORM IT PROSCRIBED TASK OF CIRCULATION OR IS THERE OTHER ACTIVITIES WHICH OCCUR THERE?

118 3. HOW DO THE INTERACTIONS DIFFER BETWEEN THE 3 DIFFERING CONDITIONS I.E. EXTERNAL, INTERNAL AND THE SPACE BETWEEN?

119 4. IS IT PRIVATE OR IS IT PUBLIC? OPEN OR CLOSED?

120 5. HOW WOULD THE CONNECTIVITY DIFFER IF IT WASN'T A PERMEABLE MEMBRANE I.E. GLASS INSTEAD OF NETTING?

121 LETS BRING IT BACK TO THE CONCEPT OF MODULARITY...

122 1. IF THIS PICTURE WERE MADE UP OF MULTIPLE BOXES EACH ONE OF THEM A HOUSE OR COMMUNITY AND THEN WRAPPED IN A PERMEABLE MEMBRANE WOULD THIS BE CLASSED AS MODULAR HOUSING? CAN THE SKIN TWIST AND CONTORT AROUND OR BETWEEN THE BOXES TO OFFER DIFFERENT LAYERS OF PUBLIC AND PRIVATE SPACES? WHAT ACTIVITY OCCURS IN THE 'IN BETWEEN' SPACES IN THIS INSTANCE?

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123 IF A SHANTY I.E. ONES OF SPACE WAS UNRAVELED, TAKEN APART, ANALYSED AND LAID OUT BARE ON A TABLE WHAT ARE THE ELEMENTS WHICH WOULD SIT THERE?

124 HOW DOES THIS SPACE RELATE TO THE OTHERS AROUND IT? HOW DOES IT FORM A COMMUNITY, A BOND, A BINDING AGENT WHICH LINKS THESE TOGETHER?

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125 HERE IS AN IMAGE FROM THE VENICE BIENNALE 'AUSTRALIAN PAVILLION' WHICH CALLED ON CREATIVE THINKERS TO REIMAGINE THE STRUCTURE OF OUR CITIES IN 2050? A LITTLE FARFETCHED BUT THE IDEA IS THERE? STACKING INDIVIDUAL PIECES TO FORM THESE LIVABLE TOWERS/ CITIES.

126 HOW DOES THIS DIFFER FROM THE TOWER OF DAVID IN VENEZUELA? DOES IT NEED TO BE THIS STRUCTURED OR IS THERE A WAY TO PROVIDE THE BONES OF SOMETHING AND LET PEOPLE RUN RIOT IN AN AD-HOC TYPE OF WAY?

127 THIS IMAGE IS REMINISCENT TO THAT OF THE TERMITE MOUND. ANYONE WANT TO RESEARCH TERMITE MOUNDS IN AN EFFORT TO UNCOVER SOME SUSTAINABLE RESPONSE TO HOUSING? I WAS AT A LECTURE AT ONE STAGE THAT SHOWED A CASE STUDY OF THE MOUND IS ONE OF THE BEST EXAMPLES IN NATURE OF SUSTAINABLE DESIGN. I.E. ITS MADE OUT OF THE EARTH, ITS TEMPERATURE IS REGULATED BY OPENING AND CLOSING VENTS WHICH ARE OPEN AND CLOSED BY THE TERMITES.

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128 ANOTHER COUPLE OF INTERESTING EXAMPLES FROM THE BIENALE WHICH SETOUT TO USE THE EXISTING BUILDING INFRASTRUCTURE AS THE BASIS FOR THERE DESIGN.

129 1. INTRODUCES THE IDEA OF INTEGRATED HOUSING INTO THE DESIGN OF BRIDGE INFRASTRUCURE AND 2. EXPLORES THE IDEA OF THE PROSTHETIC ORGANISM WHICH BASICALLY FEEDS OFF THE EXISTING BUILDINGS IN OUR CITIES?

130 AT SOME STAGE IN THE NEAR FUTURE THERE WILL BE A LARGE AMOUNT OF AGING BUILDING STOCK WHICH WILL NEED TO BE RE-APPROPRIATED OR RE-USED?

- <![CDATA[

131 1.

- <![CDATA[

132 2.

- <![CDATA[

133 START

- <![CDATA[

134 END

- <![CDATA[

135 Basic Module ?

- <![CDATA[

136 Life cycle?

- <![CDATA[

137 Fuction Module

- <![CDATA[

138 Room Module

- <![CDATA[

139 Rooming

- <![CDATA[

140 Housing

- <![CDATA[

141 Seeding

- <![CDATA[

142 House Module

143 Function - Sleeping

144 Function - Sleeping

145 Function - entertaining

146 Function - Sleeping

147 Function - entertaining

148 BED Room

149 Function - Sleeping

150 Function - entertaining

151 Function - Sleeping

152 Function - entertaining

153 BED Room

154 Bath

155 Function - Kitchen

156 Function - dining

157 DK

158 Living Room

159 Function - Kitchen

160 Function - dining

161 Ent
 162 Bath
 163 Modularity: Physically Constrained Repetition
 - <![CDATA[
 164 Beauty Vs Monotony
 - <![CDATA[
 165 Housing for the Masses
 - <![CDATA[
 166 'Modular' Man
 - <![CDATA[
 167 Micro-module
 - <![CDATA[
 168 Macro-module
 - <![CDATA[
 169 Individualisation + Identity
 - <![CDATA[
 170 Space Efficiency = Material Efficiency = Sustainable
 - <![CDATA[
 171 Mobile 'Masses'
 - <![CDATA[
 172 Barcelona City Grid
 - <![CDATA[
 173 'Space (Area + Volume)
 - <![CDATA[
 174 Lifestyle
 - <![CDATA[
 175 Style - What is a house 'supposed to' be / do / look like
 - <![CDATA[
 176 data from the Australian Bureau of Statistics indicates that new homes across Australia are
 bigger in square metre terms than anywhere else in the world.... putting more and more rooms
 in our ever-growing houses.....
 - <![CDATA[
 177 the floor area of freestanding houses at a record high..... 245 square metres We
 are bigger than the US for the first time. Our newly built homes are 7 per cent bigger than those
 in the US, double the size of those in Europe, and triple the size of those in the UK.
 - <![CDATA[
 178 AUSTRALIA
 179 EUROPE
 180 UK
 181 House sizes
 182 Vetruvian man
 - <![CDATA[
 183 ?
 - <![CDATA[
 184 Family Home?
 - <![CDATA[
 185 Reduce
 186 Re-Use
 187 Recycle
 - <![CDATA[
 188 17 Million Shipping Containers
 - <![CDATA[
 189 around the world
 - <![CDATA[
 190 Mobile
 191 Robust
 192 Compact
 193 Standardised

- <![CDATA[
194 modular - fabric
- <![CDATA[
195 Modular - spatial
- <![CDATA[
196 Modular - structural and fabric give rise to unique spatial outcomes
- <![CDATA[
197 Open Modular
- <![CDATA[
198 Open Modular System of Sustainable Houses (SAVMS) / Cso Arquitectura
- <![CDATA[
199 <http://www.archdaily.com/295004/open-modular-system-of-sustainable-houses-savms-cso-arquitectura/>
- <![CDATA[
200 SAMVS is a system of generation of industrialized open modular housing, the user can adapt it to his needs, the product can be realized in a very short time with a fixed price and with the utilization of all kinds of sustainable systems.
201 1. Generation of The System
202 -MBy the means of the combination of series of modules that correspond with the different functions of the housing, the client composes the building to his measure, depending on series of generative laws that obey the design.
203 -The client, in addition, has the possibility of choosing between series of ended proposed on catalogue, both for the interior and the exterior.
204 2. Advantages of The System
205 -The price is fixed and thanks to the industrialization of the product, very competitive prices are obtained (from 700 €/m2, included project).
206 -The time of delivery gets improved with regard to a traditional construction; the period of fabrication + montage is realized in one month and a half.
207 -The extensions of the housings are added on one of other modules and the extensions are very simple.
208 -As the fact that housings are produced in the factory, the residues are generated to minimal.
209 3. Echo – Product
- <![CDATA[
210 Sustainability
- <![CDATA[
211 How many types (pieces) does this need?
- <![CDATA[
212 Module Variation + Connector Primacy / Compatibility
- <![CDATA[
213 Draft Module Schema
- <![CDATA[
214 Modular Variation
- <![CDATA[
215 Growing Housing System
- <![CDATA[
216 GHS
- <![CDATA[
217 Basic Module - Functional Modules
- <![CDATA[
218 Adding and deleting Modules - Shape grammar
- <![CDATA[
219 Justified planning graphs - Funtinonal configuration
- <![CDATA[
220 Final Principles for GMS
- <![CDATA[
221 In order to support the growing or changing
222 lifecycle
223 , GMS starts with

224 basic modules
225 that come from housing,
226 functional types
227 (Sleeping, dining,...)
228 Basic modules have certain
229 shape types
230 like ego blocks or honeycombs.
231 Each module should be developed to support
232 sustainable design
233 Before applying the rules to generate a domestic building, GMS does
234 configuring its functions
235 with given design contexts and requirements.
236 To support the combination and links of modules, GMS considers the
237 generation rules
238 like Shape grammar (Adding, deleting, modifying,...)