SEMANTIC MEASURES FOR ENHANCING CREATIVITY IN DESIGN EDUCATION

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ABSTRACT

Analysing verbal data produced during the design activity is helpful to gain a better understanding of design creativity. To understand exchange of information in terms of creative outcomes, a semantic analysis approach was used to measure the semantic content of communications between students and teachers. The goal was to use this tool to analyse design conversations, and to investigate their relation to design creativity, assessed in terms of originality, usability, feasibility, aesthetics, elaboration, overall value and overall creativity. Abstraction, Polysemy, Information Content and Semantic Similarity were employed to explore 35 design conversations from the DTRS10 dataset. Main findings suggest that a significant relationship exists between Information Content and Originality, and between Information Content and Overall creativity of the produced design outcomes. Significant relations were also found between Abstraction, Polysemy, Information Content, and Feasibility, as well as between Semantic Similarity and Overall Value of the outcomes. Implications for the use of semantic measures for encouraging creativity in the design studio are discussed.

Keywords: Creativity, Design cognition, Design education, Semantic analysis, Design creativity

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1 INTRODUCTION

Creativity is considered as a major component of design problem solving. Analysing verbal data produced during the design activity can help to gain a better understanding about creative processes, and creative outcomes. While enabling a systematic representation and modelling of real-world processes in design problem solving, using approaches such as semantic analysis can contribute to this end. Semantic analysis allows for the quantification and comparison of information concerned with the design process, and its relation to the produced outcomes. However, not many approaches measuring the semantic content of conversations or documentation produced during the design process exist in literature. Handful exceptions are works on linkography (e.g., Goldschmidt, 2014), and latent semantic analysis (Dong, 2009). In an early example of the use of semantic analysis, Mabogunje and Leifer (1997) evaluated the design process and found that the number of nouns generated during a mechanical design project documentation was strongly associated with the scores of the project outcomes. Dong (2009) used lexical chain semantic approach to analyse linguistic appraisals in design, and differentiate discontinuities in agreement in design problem solving. Helms and Goel (2014) analysed design protocols and, based on a semantic analysis of the transcripts, extracted a schema of problem specification for biologically inspired design.

On the other hand, to the best of our knowledge, not many semantic approach-based researches were carried out to investigate design creativity in real-world settings. Few exceptions are Georgiev and Georgiev (2018), Georgiev, Nagai, and Taura (2010), Georgiev and Taura, (2014), Taura *et al*. (2012) and Yamamoto *et al*. (2009). Existing methods related to the study of creativity, such as linkography (Goldschmidt, 2014), are laborious, effortful, and narrow in the sense that are largely focused on design ideas, rather than on the semantic content of the verbalisations. Thus, it is difficult to understand what kind of information produced during the design process leads to what kind of creative outcomes. Therefore, a study relying on the semantic analysis of verbalisations can be promising to measure the semantic value of design conversations.

The approach we consider in this study has important advantages. First, it uses a number of semantic measures that enable the quantification of fundamental phenomena in design, cognitive psychology and linguistics. Such measures, which showed to be successful to study ideation in design problem, include polysemy, abstraction, information content (IC) and semantic similarity (Georgiev and Georgiev, 2018). Second, it applies systematic and domain independent representation of words (i.e., WordNet database). Third, the employed measures are faster to compute compared to other semantic analysis approaches used in the context of design conversations (e.g., Dong, 2009). Therefore, the main goal is to use the proposed semantic approach to analyse design conversations maintained in the studio, and explore the relation of the semantic measures to different aspects of design creativity.

The central question guiding the research is how and to what extent the semantic approach, measured by polysemy, abstraction, IC and semantic similarity, can help to analyse the content of the design conversations, and understand its relation to the creativity of the produced outcomes, measured by originality, usability, feasibility, aesthetics, elaboration, overall value and overall creativity. In order to address this question, we use the industrial design subset of the DTRS10 dataset (Adams, 2015).

2 CREATIVITY AND DESIGN

Creativity is referred to as the ability to express uncommon thoughts, make substantial discoveries or inventions, transform existing views in some critical respect, and experience reality from unconventional perspectives (Csikszentmihalyi, 1997). This notion is understood as a cognitive process of problem solving by means of which familiar problems are restructured and innovative ideas are generated. Creativity has been recognized as a fundamental component of design. The main reason is that design problem-solving is ill-structured, complex, and non-routine. Considering that the kind of knowledge necessary for producing successful solutions cannot be foreseen, design problem-solving is likely to stimulate and motivate the development of innovative ideas and solutions.

In spite that no comprehensive theory of design creativity has been developed so far, it is possible to find different approaches in literature sharing features to assess design creativity. Whereas some studies focus on the creativity of the product, others centre on the creativity of the process or the designer. When the assessment of creativity is about the design outcome, most studies frequently operationalized it in terms of originality, usability, value, feasibility, elaboration, and aesthetics.

Originality, recognized as one of the most important characteristics of creativity, reflects the extent to which a product differs from other more familiar ones. Originality is defined by Guildford (1981) as the statistical rareness of the outcome. However, creative design products can not only be original, novel, and unexpected, but also valuable and useful (Sarkar and Chakrabarti, 2011). Valuable designs must be recognized by society to worth some merit. To be useful, designs should respond to practical needs and requirements, as indicated by the task (Siang *et al*., 2018). Usability is considered in relation to performance, efficiency, and user satisfaction. Elaboration (Guildford, 1981), on the other hand, has to do with the level of detail into which a product is developed. Design aesthetics refers to the visual appealing of a design representation. The assessment of aesthetic value is related to the affective and sensory appreciation of an artefact (Zangwill, 2014). In addition to these characteristics, creative products should be feasible, and therefore they not remain as just creative ideas, but can potentially be materialized or achieved in real practice (Kreitler and Casakin, 2009).

2.1 Creativity in design education: The design review

The assessment of design creativity in the form of criticism is central in the educational curriculum of design schools. This normally occurs in the design studio, where students acquire theoretical and practical and knowledge while they develop concepts and ideas for their design products (Cross, 1983). During the design studio sessions, also known as design reviews or design critique (also known as design 'crits'), students learn to think and behave as a designer while they reflect upon the creativity of their outcomes (Christensen and Ball, 2016). Teachers, from their side, evaluate and criticize the produced design outcomes, suggesting changes and actions to be taken over the design (Demirbas and Demirkan, 2003). The 'crit' sessions are fundamental for training students in the development of their solutions, and for supervising their progress during the process. Depending on the task, critique sessions can adopt different modalities, such as personal crit, group crit, and juries (Goldschmidt *et al*., 2015). Whereas a main goal of the personal crit is to communicate and transmit feedback between students and teachers, the group crit is more participative and dynamic, and serves to expose students to new opinions and views from other pairs. Juries are more formal, and their purpose is to allow an overall evaluation of the students' progress. Guest professionals, other than the teacher, are invited to participate in sessions that generally takes place in the middle and end of the semester.

The dialogues established between teachers, students and guests throughout the different review sessions have a significant effect in the learning and teaching experiences (Ashton, 1998). Hence, an effective communication may enhance the chances that the content of the envisioned message transmitted by teachers and invited professionals will be better understood by the student. The type of information involved in such communication process (Uloglu, 2000) may also affect the perception and development of design creativity. However, what type of information is generated and communicated during these interactions, and how this information may contribute to enhance what aspects of design creativity has yet to be addressed. Therefore, the present study will identify nouns, and classify them according to semantic measures (see next section) generated in the review sessions, and will explore their potential relations with the creativity of the produced design outcomes.

3 SEMANTIC ANALYSIS AND DESIGN PROBLEM SOLVING

The semantic content of verbalisations constitutes an important source to quantify and compare the information generated and communicated during interactions and conversations. Semantic analysis approach can help to depict human thinking as a kind of network wherein a concept can lead to many other related concepts. In design problem solving, semantic analysis in allows the representation, modelling and quantification of idea generation (Georgiev *et al*., 2010; Taura *et al*., 2012; Yamamoto *et al*., 2009), information processing activities (Cash *et al*., 2014) and other high level mental processes.

In the last decade, semantic approaches that use natural language processing such as lexical chain analysis have been employed to differentiate discontinuities in agreement in design problem solving (Dong, 2009). They were successful mainly in detailing forms of language for expressing judgments, as well as for identifying semantic resources in linguistic appraisals in the context of design conversations (Dong, 2009). However, while such approaches offer critical insights into the design problem solving process, they fail to address design creativity specifically.

In order to bridge this gap, the present study considers an alternative semantic analysis approach to the more classic existing ones (Mabogunje and Leifer, 1997; Hill *et al*., 2001; Dong, 2009). The approach, which it is not computationally demanding, employs measures of fundamental phenomena in design, and a systematic representation. Four semantic measures are used to quantify fundamental process with regard to creativity and design problem solving, which includes: polysemy, abstraction, IC, and semantic similarity.

Polysemy is defined as the quality of a word of having multiple meanings. Words can range from having single meaning (be monosemous) to have large number of meaning (e.g., word 'right' has eight noun meanings). It is identified as an essential manifestation of the flexibility, adaptability, and richness in meaning potential (Fauconnier and Turner, 2003; Georgiev and Taura, 2014). In particular, existing words are employed to express new meanings arising in conceptual blending (a conceptual integration where concepts are mixed in a subconscious process). Consequently, combinations of inappropriate inputs become meaningful in the output (Fauconnier and Turner, 2003).

Abstraction is defined as a generalisation from specific instances that possess a lower level of detail in information. Thus, an abstraction is a type of thinking where common features are identified (abstracted). In the psychology of creativity domain, it is well known that abstract compared to specific ways of thinking lead to novel and open-ended ideas (Ward *et al*., 2004). In general, reliance on specific knowledge is seen as problematic, in particular when the properties of such knowledge constrain new potential ideas. Hence, abstraction is considered to be an important characteristic of creative idea generation.

In the language and thinking domain, **information content (IC)** is defined as the amount of information conveyed by a particular unit of language in a specific context (Georgiev and Georgiev, 2018). IC measures the degree of informativeness of a unit. Hence, units with higher IC have a lower probability of occurrence. IC is seen as a fundamental phenomenon in human language and thinking that can be quantified in different ways. For example, IC was found to be beneficial to measure design fixation during idea generation activity (Gero, 2011).

Semantic similarity can be used to quantify the strength of semantic relationships between units or instances of language. Indeed, the most typical measures used in natural language processing are those related to semantic similarity (e.g., Resnik, 1995). They rely on an is-a taxonomy that allows quantifying how alike are two words, and how closely they represent human similarity judgements. A document-level semantic similarity was used to quantify how alike two topics in design are (Hill *et al*., 2001). Georgiev and Georgiev (2018) showed that semantic similarity measures can be useful in the identification and representation of essential processes in design thinking.

Only a few studies focused on the relationship between semantic analysis approach and creativity. In one of these, polysemy was found to correlate significantly with the originality of the ideas generated in a concept synthesis task (Taura *et al*., 2012). Georgiev and Taura (2014) also demonstrated that polysemy was a main feature of successful ideas developed in design conversations. Another study on design problem solving showed that semantic similarity was successfully used to quantify convergence and divergence in design thinking (Georgiev and Georgiev, 2018).

Several methods based on semantic networks have been developed recently to analyse design activities (Georgiev and Georgiev, 2018; Georgiev *et al*., 2010), and design thinking process based on dynamics of linked data (Cash *et al*., 2014). The process of discussing a problem and finding a solution can be understood in terms of a dynamic semantic network that changes with time (Georgiev and Georgiev, 2018). Main advantages of using semantic networks for the sake of analysing transcribed textual data from real conversations are: i) the applicability of the method for studying any cognitive processes occurring in the human mind, including processes that cannot be parsed into design moves, and ii) the robust computation of a large number of objective theoretic measures of information.

Consequently, the present research employs semantic networks to represent concepts (i.e., meanings, and words) as nodes, and relationships as links between nodes in a graph. A practical way to analyse design conversations is by computing theoretic measures (i.e., abstraction, polysemy, IC and semantic similarity) from constructed graphs that are based on conversation transcripts, where the participants exchange and share ideas about the design task. The semantic measures are calculated (or quantified) from conversations that are grounded in existing experimental research on design creativity, cognitive psychology and linguistics. The research hypothesis is that these measures can be successfully used to predict the creativity of design outcomes.

4 METHOD

The information analysed in this study corresponded to 35 design review conversations from the DTRS10 dataset. Six junior students and six graduates, all majoring in Industrial Design, two experienced design teachers, and other stakeholders such as clients and professional experts participated in the tasks. One student was omitted from the study due to data missing from some of the conversations.

Real-world design review conversations are an outstanding source of data to gain insight into the constructs of design thinking. The goal of each design session was to discuss and provide feedback to the students to develop a solution, intended for a real client. Each session lasted about 15 minutes long. The task for the junior students called for the design of "Impromptu" seating places for a real client. They should provide solutions to collaborative work environments, and be versatile in corporate and vertical market segments (For an example of a design outcome see Figure 1a). The task for the graduate students consisted in designing for an "Outside the Laundry Room" place. It was aimed at exploring the laundry process for homeowners. A design requirement was to develop solutions that would help enhance the laundry experience (Adams and Siddiqui, 2013).

The assessment of the creativity metrics was carried out by two experienced independent referees, who used a 1 to 5 value Likert scale ranging from low (=1) to high (=5) ratings. They evaluated the design outcomes over seven factors described and justified in Section 2 that included: Originality (how different is the outcome from standard/other solutions); Usability (performance, efficiency, response to practical needs); Feasibility (technology/materiality); Aesthetics (beauty, visual appealing); Elaboration (level of detail/complexity); Overall Value (as perceived by society, or a cultural group); and Overall creativity (based on Amabile's (1996) Consensual Assessment Technique [CAT]). CAT is considered as a reliable measurement tool in which appropriate evaluators assess the general creativity of products based on their expert knowledge).

Cohen's kappa coefficient was run to determine the level of agreement between the referees on their assessments of the creativity of the final products. Table 1 shows that there was a substantial and significant agreement for all the assessed variables.

Table 1. Cohen's Kappa k evaluation of agreement between two referees.

	Original	Usable	Feasible	Aesthetic	Elaboration	Overall Value	Overall Creativity
Kappa	0.883	0.780	0.885	0.762	0.883	0.644	0.872
Sig.	0.000	0.000	0.000	0.000	0.000	0.000	0.000

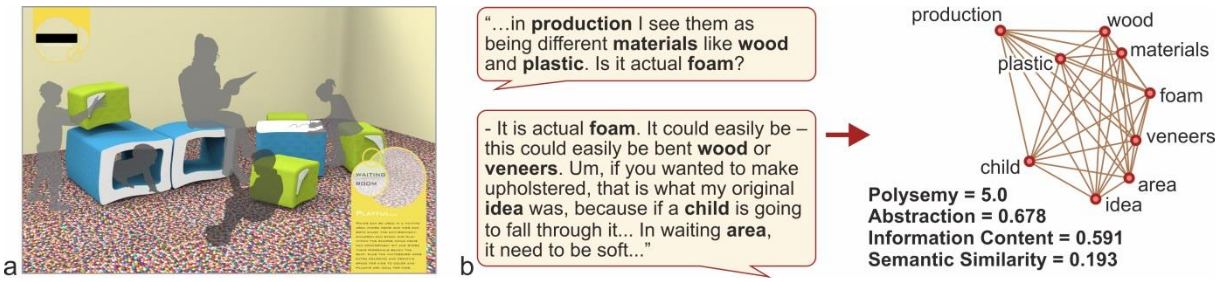

Figure 1. Examples of (a) a design outcome by a junior student; (b) a conversation depicting semantic measures

All design conversation sessions were analysed as a whole. In order to automate the measure of semantic values, standard natural language processing tools are employed to extract nouns from the design conversations. Then, a novel method based on Python scripts and dedicated software is used to calculate the outlined semantic measures from these nouns (For further information see Georgiev and Georgiev, 2018). The four semantic measures of polysemy, abstraction, IC and semantic similarity were calculated as average values of all the conversations maintained by each student (Figure 1b). Calculations are based on existing graph-theoretic and information-theoretic formulas (Resnik, 1997; Blanchard, 2008).

The semantic approach used in this research included the subsequent steps: First, to construct semantic networks of nouns utilized in the conversations, the transcripts obtained from the 10th Design Thinking Research Symposium dataset (Adams, 2015) were cleaned to eliminate any indications of non-verbal expressions, such as "[Crosstalk]", speaker names and images. In a second step, the textual data was processed using part-of-speech tagging with the Natural Language Toolkit (NLTK) (Bird *et al*., 2009).

Thereafter, only singular and plural nouns were extracted. Aided by Python scripts, all the nouns were processed by converting plurals to singular forms, and by removing those nouns that were not listed in the WordNet database.

The following is a sample of four graph (network) theoretic measures that were computed with WordNet 3.1 is-a hierarchy of nouns. These measures use network composed of word nodes (connected in is-a hierarchy), meaning nodes (terminal nodes called leaves that represent all the meanings of a word node), and directed links between the nodes (Georgiev and Georgiev, 2018):

- Polysemy is the number of direct links between a word node A and its meaning nodes, accounting for the number of meanings of the word node (Georgiev and Taura, 2014). For example, 'car' node has five meaning nodes of 'auto', 'railcar', 'gondola', 'elevator car' and 'cable car'.
- Abstraction is the normalized fraction of the shortest path distance from the root word node to a word node A, and the maximal shortest path from the root in the network. Abstraction accounts for how generalized is the word node compared to the most specific instance (Georgiev and Georgiev, 2018).
- Information Content (IC) is the bits (amount) of information carried by a word node inside the graph. The IC is measured as a normalized fraction of the number of leaves of the word node, and the maximal number of leaves in the network (Blanchard, 2008; Georgiev & Georgiev, 2018).
- Semantic Similarity of two word nodes, A and B, is measured by the IC of the least common subsumer of two words (Resnik, 1995), essentially quantifying how alike are the two word nodes. The least common subsumer (LCS) of A and B is the most specific word node which is an ancestor of both A and B in the is-a hierarchy (e.g., the LCS of 'car' and 'boat' is 'vehicle').

5 RESULTS

In order to examine the relation between the four semantic measures and the seven creativity measures we conducted correlation analyses, and reported uncorrected p-values (See Table 2). The results showed significant correlations between Feasibility and Polysemy, Abstraction and IC measures. Significant correlations were also found between IC and Originality, Feasibility, and Overall Creativity. Finally, Similarity was found to correlate with Overall Value.

Table 2. Pearson correlations between semantic measures and creativity evaluations (n=12).

Pearson Correlation		Originality	Usability	Feasibility	Aesthetics	Elaboration	Overall Value	Overall Creativity
Polysemy	Corr.	-0.016	0.535	0.699*	-0.199	0.157	0.482	-0.115
	Sig.	0.962	0.073	0.011	0.535	0.626	0.113	0.721
Abstraction	Corr.	-0.347	0.255	0.811**	-0.279	-0.088	0.075	-0.293
	Sig.	0.269	0.424	0.001	0.379	0.786	0.817	0.355
IC	Corr.	0.638*	-0.221	-0.661*	0.523	0.523	0.178	0.753**
	Sig.	0.026	0.489	0.019	0.081	0.081	0.579	0.005
Similarity	Corr.	0.116	0.549	0.525	-0.068	0.150	0.660*	-0.046
	Sig.	0.719	0.064	0.080	0.833	0.642	0.020	0.887

In order to examine the relation between the different semantic measures and the creativity of the design product, we performed several regression analyses with semantic measures as predictors, and creativity factors as dependent variables. The first regression corresponds to the originality of the final product. The overall results of the semantic variables are significant and indicate that only the variable concerned with IC was related to Originality (See Table 3).

Table 3. Regression analysis of the semantic measures on the originality evaluation

	Sum of Squares	df	Mean Square	F	Sig.
Regression	16.460	4	4.115	4.721	0.037
Residual	6.102	7	0.872		
Total	22.563	11			
R Square 0.854; Standardized Beta Coefficients; Polysemy -0.204 t = -0.275 ns; Abstraction -0.292 t = -1.033 ns; IC 0.820 t = 3.413 p < 0.05; Semantic Similarity 0.877 t = 1.331 ns					

The second regression corresponds to the feasibility of the final product. Although the overall results of the semantic variables are significant, no variable was related to Feasibility (See Table 4). It should be noted that Polysemy, Abstraction, and Semantic Similarity show trends towards significance in the regression (p = 0.071 ns, p = 0.088 ns, and p = 0.089 ns respectively).

Table 4. Regression analysis of the semantic measures on the feasibility evaluation

	Sum of Squares	df	Mean Square	F	Sig.
Regression	11.934	4	2.983	9.812	0.005
Residual	2.129	7	0.304		
Total	14.063	11			
R Square 0.921; Standardized Beta Coefficients; Polysemy 1.185 t = 2.131 ns; Abstraction 0.419 t = 1.985 p = ns; IC -0.288 t = -1.601 ns; Semantic Similarity -0.971 t = -1.970 ns					

The third regression corresponds to the overall value of the final product. The overall results of the semantic variables are highly significant and show that from the four measures, the variables concerned with Semantic Similarity and IC were related to Overall Value (See Table 5).

Table 5. Regression analysis of the semantic measures on the overall value evaluation

	Sum of Squares	df	Mean Square	F	Sig.
Regression	7.569	4	1.892	11.411	0.003
Residual	1.161	7	0.166		
Total	8.729	11			
R Square 0.931; Standardized Beta Coefficients; Polysemy -0.930 t = -1.783 ns; Abstraction -0.046 t = -0.233 ns; IC0.563 t = 3.342 p < 0.05; Semantic Similarity 1.846 t = 3.997 p < 0.01					

The fourth regression corresponds to the overall creativity of the final product. The overall results of the semantic variables are significant and indicates that only the IC was related to Overall Creativity (See Table 6).

Table 6. Regression analysis of the semantic measures on the overall creativity evaluation

	Sum of Squares	df	Mean Square	F	Sig.
Regression	7.709	4	1.927	4.467	0.042
Residual	3.020	7	0.431		
Total	10.729	11			
R Square 0.848; Standardized Beta Coefficients; Polysemy 0.214 t = 0.282 ns; Abstraction -0.132 t = -0.459 ns; IC 0.954 t = 3.893 p < 0.01; Semantic Similarity 0.297 t = 0.442 ns					

The fifth regression corresponds to the usability of the final outcome. The overall results of the semantic variables are not significant, and no semantic variable was related to this creativity factor (See Table 7).

Table 7. Regression analysis of the semantic measures on the usability evaluation

	Sum of Squares	df	Mean Square	F	Sig.
Regression	4.230	4	1.058	.806	0.559
Residual	9.186	7	1.312		
Total	13.417	11			
R Square 0.562; Standardized Beta Coefficients; Polysemy 0.355 t = 0.300 ns; Abstraction -0.114 t = -0.254 ns; IC 0.072 t = 0.189 ns; Semantic Similarity 0.311 t = 0.297 ns					

The sixth regression corresponds to the aesthetic evaluation of the final design outcome. The overall results of the semantic variables are not significant, and consequently no semantic variable was related to this factor (See Table 8).

Table 8. Regression analysis of the semantic factors on the aesthetic evaluation

	Sum of Squares	df	Mean Square	F	Sig.
Regression	3.648	4	0.912	1.157	0.405
Residual	5.518	7	0.788		
Total	9.167	11			
R Square 0.631; Standardized Beta Coefficients; Polysemy -0.924 t = -0.833 ns; Abstraction 0.013 t = 0.032 ns; IC 0.557 t = 1.555 ns; Semantic Similarity 1.078 t = 1.097 ns					

The seventh regression corresponds to the elaboration of the final product. The overall results of the semantic variables are not significant, and no semantic variable was related to Elaboration (See Table 9).

Table 9. Regression analysis of the semantic factors on the elaboration evaluation

	Sum of Squares	df	Mean Square	F	Sig.
Regression	6.411	4	1.603	2.412	0.146
Residual	4.652	7	0.665		
Total	11.063	11			
R Square 0.761; Standardized Beta Coefficients; Polysemy 1.091 t = 1.177 ns; Abstraction -0.202 t = -0.573 ns; IC 0.849 t = 2.834 p < 0.05; Semantic Similarity -0.353 t = -0.430 ns					

6 DISCUSSION

Three major groups of findings concerned with the semantic measures and their relation to the creativity factors are discussed. These include: i) Polysemy, Abstraction, and IC in relation to Feasibility; ii) IC in relation to Originality and Overall creativity; and iii) Similarity in relation to Overall value.

6.1 Design feasibility and generalization

Findings suggest that ideas with higher Feasibility are the outcome of design conversations involving higher levels of Polysemy and Abstraction, as well as lower IC. This means that being fluent in abstract words and words with a higher number of meanings might lead to outcomes that can be materialized in reality. No prior studies relating feasibility with semantic measures of Polysemy, Abstraction, and IC were found in literature. However, the closest ones suggest that a relation exist between Polysemy, Abstraction (see next subsection), and Creativity (Taura *et al*., 2012; Ward *et al*., 2004).
Based on these results, recommendations for design studio education can be suggested regarding instructional strategies that can be used when the goal is to develop feasible solutions. For example, information exchange among designers should be characterized by as less specific IC as possible. This can be achieved using terminology with a higher number of meanings that at the same time should tend to be abstract. Consequently, the design conversation might be characterized using common language and generalizations. Identification of less specific IC by means of automatized programs can be used online, as a first step to assist designers in producing feasible solutions. For example, instructional strategies can be provided in online courses aimed at attaining likely goals. While the system can inform about the level of specificity of the information exchange, eventually it could also make suggestions to increase or reduce the specificity of the IC to a desired level.

6.2 Design creativity and specificity

Notably, IC was found to be a significant predictor contributing to Originality, and Overall creativity factors, as indicated by the significant results from the regressions analyses. These findings are supported by Gero (2011), who observed that a sharp drop in IC was seen to be related to design fixation (defined as a contrasting feature of creativity). Likewise, Georgiev and Georgiev (2018) found that when IC increases, the generation of successful ideas – known to lead to creative outcomes, was also increased. Other studies found significant relations between Creativity (measured as the originality of the produced ideas) and Polysemy (Taura *et al*., 2012), and between Creativity and Abstraction (Ward *et al*., 2004), which is not the case in the present study. Considering that IC can be defined as the inverse probability of ordinary language occurrence, it is suggested that fluency on domain-specific and uncommon language can be used to support the generation of Original and Overall creative outcomes. This can be implemented by means of automatized systems monitoring online design courses.

6.3 Design value and similarity

Semantic Similarity was found to contribute to the Overall value of the outcomes. This means that when the Semantic Similarity of the conversations is increased, the Overall value of the design outcomes also increases. In previous studies, Semantic Similarity was seen to be positively related to the self-perceived evaluation of the quality of the design outcomes (Georgiev *et al*., 2008). Therefore, it can be argued that employing instances that are close one another, aided by automated evaluations for the sake of communicating and exchanging information, can enhance the chances that a team working in a specific context – i.e., design students and teachers, or professional designers, would perceive a design outcome as having higher added value.

7 CONCLUSION

In this study we explored the validity and benefit of using the semantic approach to analyse design conversations in the studio, with a focus set on design creativity. To this aim, we employed Abstraction, Polysemy, IC and Semantic Similarity as major semantic measures which were easy to compute and helpful to understand fundamental phenomena in design. The main findings demonstrated the significant relationship that exists between IC and Originality, as well as between IC and Overall creativity. Results also outlined the significant relations that exist between Polysemy, Abstraction, IC, and Feasibility, as well as between Semantic Similarity and the Overall Value of the produced design outcomes. Moreover, findings suggested how certain semantic measures can potentially be used as predictors of design creativity. In this regard, designers that are fluent in IC can be considered to be highly creative and therefore able to produce creative outcomes. These results may pave the way for implementing future knowledge-based systems that could analyse conversations in real-time to identify the IC of certain designers, and predict how potentially creative their outcomes could be. Similarly, the semantic approach can be implemented for identifying creative candidates in admission procedures of high education departments interested in design. Moreover, intervention programs—mainly those employed in online courses—that might be interested in encouraging design creativity will benefit from implementing the present findings in the design studio. A major issue to be addressed could be how to implement educational approaches in order to stress the IC aspect in design conversations maintained between teachers and students during design sessions.
The present can be seen as an explorative study based on a small sample of students. Thus, rather than centring on the research findings themselves, we were more interested in learning about the validity of the approach in analysing and capturing the semantic content of the conversations, and their importance for design creativity. This work is a part of a larger study that we plan to carry out in the future to enhance the understanding about the contribution of the semantic approach on design creativity, which will include a larger sample of participants with different levels of knowledge and expertise, such as junior and graduate students, as well as teachers and clients.

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