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ORIGINAL PAPER

The relationship between personal intrinsic factors towards a design problem and the degree of novelty and circularity

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Abstract
The aim of this work is to determine how personal intrinsic factors towards a design problem are related to novelty and circularity. A deeper understanding of this relationship will be a valuable aid when it comes to making an adequate selection of design teams. The factors studied are the level of the designer's motivation, relevance, knowledge and affinity with regard to the design problem. To this end, a study was conducted with 35 novice designers, organised in groups of between two and five members. Each group had to propose a conceptual solution to two different design problems. Novelty was assessed using the SAPPhIRE causality model (which stands for State–Action–Part–Phenomenon–Input–oRgan–Effect) and the Circular Economy Toolkit was applied to measure circularity. The results show that as motivation, level of knowledge, perception of relevance and affinity for the problem increase, the solution displays greater novelty and less circularity, although for circularity, the difference is not statistically significant.

Keywords Circularity assessment · Novelty assessment · Product design · Conceptual design · Intrinsic factors

1 Introduction

Today, designers face two major challenges, among others, while carrying out their work: to achieve innovative products, and to respond to society's growing need to take care of the planet. A large amount of research has been conducted on both aspects and can be divided into two large blocks: designers' creativity and their results, and sustainable design, taking into account the considerations of the circular economy (CE).

The circular economy consists in using the smallest number of resources by ensuring they stay in circulation for as long as possible and keeping waste generation to a minimum. Product design is a crucial agent in introducing the CE into the productive system and especially so if it is implemented according to the principles proposed by the Ellen MacArthur Foundation (Ellen MacArthur Foundation 2013):

Design in such a way as to avoid generating waste.

Increase life span through product diversity (such as modular, convertible or repairable products).

Use renewable energy sources, if necessary.

Consider how products interact with each other and their different components to minimize resource usage.

Take into account the waste that will be generated at the end of the product's useful life and allow for it to be introduced back into the system in a biological or technological way (biodegradable, recyclable materials, etc.).

Designers are increasingly of the opinion that this introduction of the concept of circularity into product design is necessary and that it is relatively easy, perhaps not for all the fields covered by the umbrella of the CE but at least for the most basic and relevant ones in product design (Ruiz-Pastor et al. 2017). Thus, there is a growing amount of expectation and interest among both designers and consumers in taking up the new challenges. This interest is also about generating more responsible results, as regards minimizing both biological and technological resources and, therefore, the introduction of the CE (Brass and Mazzarella 2015). Efforts are therefore being made to further the transition towards the CE, although without an agreed monitoring framework (Prieto-Sandoval et al. 2016). There is, however, a wide

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range of methodologies covering the different aspects of the transition towards a CE.

Mitchell and Walinga (2017) maintain that sustainability requires creative ways of thinking and new ideas. D'Orville (2019) also defends that achieving long-term sustainability requires coming up with new solutions, which imply creativity. A major product innovation is, then, a really new product and with radical innovation (O'Connor 2008) that usually goes through several improvements in terms of minor product and systems, with typically vague performance criteria when it appears and in which the user plays an important role in the ultimate form of the product (Abernathy and Utterback 1978). This leads to the designer's other challenge, which is obtaining creative and functional products. In this sense, Designers commonly face ill-structured design problems, which fail to set out any clear restrictions, include multiple possible solutions and lack a clear consensus on the best solution (Jonassen 1997).

The consensus among researchers as to its general definition is that creativity involves the generation of ideas that are novel and appropriate (Sarkar and Chakrabarti 2008). Usually, the term "appropriate" is related to feasibility or usefulness in product design. In our case, the circular demands can, in turn, be interpreted as a part of how appropriate the design is, playing an important role in the product definition, together with the novelty and being, in this way, fostering creativity through novelty and circularity together.

Concerning circularity assessment, a recent analysis performed by Parchomenko et al. (2019) identified three main groups of metrics: resource-efficiency, materials stocks and flows, and product-centric. Examples of product-centric metrics include the Material Circularity Indicator (MCI) (Ellen Macarthur Foundation and Granta Design 2015), C2C Certified Product Standard (Cradle to Cradle Products Innovation Institute 2019), Longevity indicator (LONGEVITY-I) (Franklin-Johnson et al. 2016), Product level circularity metric (PCM) (Linder et al. 2017), or the Circular Economy Toolkit (CET) (Evans and Bocken 2013). Many of these product-centric metrics require quantitative data on material flow ratios, years of duration, etc. Yet, when creative solutions are proposed during the conceptual design phase, these data are not defined quantitatively. One of the metrics that can be applied even in the initial stages of design is the CET, as it uses an evaluation questionnaire that covers 33 parameters divided into 7 categories. Compliance with these parameters is defined by choosing one of three qualitative levels: high (0)/medium (1)/low (2).

Regarding the personal intrinsic factors of designers, on the other hand, studies as Lin et al. (2013) or in Ekemba and Emurla (2017) define the intrinsic factors as the internal attributes of consumers' personal taste for products, which works as motivating influence. Personal intrinsic factors, also called personal beliefs, are inherent and relating to the essential nature of a person (Zarei and Sharifabad 2012). There are more studies in which they are also mentioned as personal beliefs (Vohs et al. 2012), psychological factors (Mocci et al. 2001), self-concept features (Zarei and Sharifabad 2012) or personal factors (Baloglu and McClearly 1999; San Martin and Rodriguez del Bosque 2008). The intrinsic factors are relatively stable and are stored in the memory, they can concern to objects or behaviours that are intrinsically relevant to the individual (Celsi and Olson 1988). Personal intrinsic factors are usually measured in individuals by indexes or scales (Majchrzak and Cotton 1988), but the most common assessment of the factors is through surveys (O'Reilly and Caldwell 1980; Lewis and Shan 2020) or test and questionnaires (Gramb and Vogel-Heuser 2015).

Motivation is one of the most considered personal intrinsic factors in the literature (Taylor 2021; Özdemir 2021; Terlato 2018; Zarei and Sharifabad 2012; Robinson et al. 2005). This study considers four intrinsic personal factors: motivation, for being the most contemplated in literature, and perception of knowledge, relevance and affinity because these three factors could presumably be related to motivation. Motivation as well as the perception of having knowledge are considered self-concept features (Zarei and Sharifabad 2012). Affinity and relevance are considered personal factors concerning objects (Celsi and Olson 1988). The relationship between the personal factors would be analysed in this work.

An activity can be considered intrinsically motivating if it provides value to the individual without any external source of satisfaction, especially satisfying the human needs of manipulation, curiosity and exploration (Staw 1989). Motivation is shown in the literature as a critical competence in the performance of designers (Robinson et al. 2005). It is defined as the engagement in an activity with an inherent interest and the perception of enjoyability and with an association with a valuable outcome (Kunrath et al. 2020). Motivation is also understood as a force that moves interaction and belongs to the person, but that it could be also caused by the system (Piccolo and Baranauskas 2012). The intrinsic motivation (IM) is the desire of a person to under-take an activity by itself and not by the achievable end (Lepper et al. 1973). Some factors can influence IM, for instance, the controlling aspect can decrease it and the feedback aspect increases it through the enhancement of the competence sense of the person (Deci 1972). Differently to intrinsic motivation, extrinsic motivation focuses on the external reward, which drives the person's behaviour. Motivation is one of the essential aspects of creative behaviour and some studies claim that the problem-solving abilities are not enough if there is no desire to solve the problem (Zimmerman and Campillo 2003).

Amabile (1983; 1996) conducted a number of experiments that suggest that the degree of creativity reached is reduced as the IM decreases. This argument has been expanded by Morosanu and Crilly (2018), who also postulate that IM enhances creativity, while the extrinsic orientation can inhibit it. An argument frequently defended in this respect is that IM helps individuals generate creative ideas, because they feel excited about their work and maintain an interest in carrying out the task (Elsbach and Hargadon 2006). Yet, the results of many of the studies that seek to establish a relationship between motivation and creativity conducted to date have been of little significance (Shalley and Perry-Smith 2001; Shalley et al. 2004). Gilson et al. (2012) fine-tuned the search a little more by distinguishing between types of creativity, their results showing that IM has a statistically significant relationship with radical innovation but not with incremental innovation. Moreover, Medeiros et al. (2017) include IM as one of the fourteen lines that are positively associated with the development of creative techniques.

Intrinsic motivation is also correlated with a waste minimization behaviour (Gilli et al. 2018). At this point, people with a strong environmental self-identity perform pro-environmental behaviours by their own, without expecting any type of external reward (van der Werff et al. 2013). Designers, on the other hand, have an intrinsic motivation to reduce the impact on the environment and society of the products that they design, according to Sumter et al. (2017), which is related also to circular product design. In line with this, this intrinsic environmental motivation of the designers could lead to solving the design problems in a more circular way.

Hence, despite there are studies that point to a correlation between intrinsic motivation and creativity, other works narrow down this effect only to radical innovation cases. So, it is needed to go further in this concept, to verify if the intrinsic motivation affects directly to the novelty factor, and if it has influence in the circularity results.

The concept of relevance arises from the state that if a user of an information retrieval system has information need, it is reasonable to say that this information is relevant to the system (Cooper 1971). According to Schamber et al. (1990), the literature has a view of relevance as a multidimensional cognitive concept dependent on the users' perception of information and their information need situations, which is dynamic but measurable if it is approached conceptually from the user's perspective. Relevance could be included as a part of the intention of a person (Cosijn and Ingwersen 2000). Nevertheless, no previous studies have been found relating the relevance of the design problem topic for designers with the novelty and the circularity of the results they provide for solving it.

According to Stompff (2003), affinity is an innate attitude of the human being that is individual and involves personal preferences. From the design perspective, it is difficult to use these innate attitudes as a design starting point, since they are innate and personal, but some attitudes seem to be common, like the affinity for some items. Product design, likewise, reflects these innate attitudes (Stompff 2003). The work of Inoue et al. (2017) shows that, in design problems that involve affinity and knowledge regarding the problem, such as a chair, giving designers little information seems to lead them to present a greater variety of conceptual alternatives and to make them more unexpected, compared to when they are provided with more visual information about the problem. Several studies refer to affinity as empathy. The results of some of them have shown that, a lower degree of empathy with the design problem, leads to a lower level of competence in conceptual design solutions. In these cases, Empathy helps to rule out the initial concepts in favour of alternatives that better suit the design requirements (Kim and Ryu 2014). Nonetheless, Kim and Ryu (2014) also found that a lower degree of empathy with the design problem leads to a better solving-problem process and, consequently, more appropriate design alternatives. Therefore, these studies would defend that more appropriated outcomes are achieved with low affinity, but variety and unexpectedness increase with high affinity. There are no known studies concerning the effect of affinity on circularity results.

Knowledge perception is defined by Lyubashits et al. (2016) as the sociocultural awareness understood as intellectual development. Also, Takvam (2010) defines this concept as an idea, belief or image someone has as a result of how they see or understand something. The perception of having knowledge and the flexible processing of knowledge are one of the central influences on creativity. It has also been observed that novice designers tend to solve the problem by trial and error and are unaware of the design strategies that could help them. This leads them to overlook part of the knowledge needs that would help them solve the problem (Ahmed et al. 2003). In addition, experts point out more information needs and sources that are relevant to the task at hand (Björklund 2013). Lyubashits et al. (2016) relates creativity with the perception of having knowledge. Creativity requires knowledge and the more range and width of knowledge, the better it is, as creativity requires knowledge to be processed (Chakrabarti 2003). In the design activity, knowledge is influenced by the perception of the design problem context and the knowledge about it (Sim and Duffy 2003). However, no studies have been found that identify a relation between the perceived knowledge of a problem topic, and the circularity of the results. Table 1, shows a summary of the personal intrinsic factors' definitions, studied in this work.

Concerning the relationship among these factors, the relationship between knowledge and affinity (Ito and Leung 2020), the relationship between motivation and affinity (Li et al. 2011; StGeorge et al. 2014) and between motivation and the perception of having knowledge

Table. 1 Personal intrinsic factors definitions.

Personal intrinsic factor	Definition	References
Intrinsic Motivation	Engagement in an activity with an inherent interest and the perception of enjoyability and with an association with a valuable outcome	Kunrath et al. (2020)
	An activity can be considered intrinsically motivating if it provides value to the individual without any external source of satisfaction	Staw (1989)
Relevance	Multidimensional cognitive concept dependent on the users' perception of information and their information need situations, which is dynamic but measurable if it is approached conceptually from the user's perspective	Schamber et al. (1990)
Affinity	An innate attitude of the human being that is individual and involves personal preferences	Stompff (2003)
Perception of having knowledge	Sociocultural awareness understood as intellectual development	Lyubashits et al. (2016)
	An idea, belief or image someone has as a result of how they see or understand something	Takvam (2010)

(Lyubashits et al. 2016) have been studied separately. There is no research about the relationships between all these four factors. It would be interesting to know if they are correlated to have fewer variables to control when managing the design problem solving, to ultimately improve this process.

However, there are no studies relating circularity with neither motivation, knowledge, relevance nor affinity. Moreover, as seen above, there are only studies relating motivation and knowledge with creativity considering it as whole. It would be interesting to expand knowledge about this to improve the addressing of design problems according to the intrinsic personal factors of each designer. This way, it would be possible to optimize the fulfilment of design requirements, circularity in this case, without affecting the novelty of the results.

2 Aim and research questions

The aim of this research is to broaden the knowledge about the relationships between the intrinsic factors and the degree of novelty and circularity obtained during the conceptual design phase. The research questions are:

- R1: When the intrinsic motivation increases, is there a higher novelty and circularity?
- R2: When the level of affinity about a design problem is higher, is there a higher novelty and circularity?
- R3: When designers perceive a design problem as more relevant, is there a higher novelty and circularity?
- R4: When the level of knowledge about a design problem is higher, is there a higher novelty and circularity?
- R5: Is there correlation between the intrinsic factors: intrinsic motivation, affinity, relevance and knowledge?

3 Methodology

3.1 Design experiment

The experiment was conducted with the collaboration of a group of 35 students with the same demographics (language, culture, background) from the last year of the Bachelor's Degree in Design Engineering. All the participants therefore had the same training and ages ranging between 20 and 32 years (M = 22.48, DT = 2.74), 18 females and 17 males. They were undergraduate and without professional experience in the design field. All have received training on circular economy during the degree and, in addition, prior to the first session they were given a half-hour training as a reminder of the subject. The activity was carried out in two sessions, which each student chose depending on the time they had available for such a purpose. To emulate the work in design studios, designers were distributed in teams. They were randomly assigned to teams, each consisting of 3–4 members with a total of 11 groups, distributed in both sessions., in which the communicative behaviour of the designers is inherent to the design process (Chiu 2002; Valkenburg and Dorst 1998).

The students were asked to generate concepts that solve two different design problems: one that they could be expected to be able to relate to (higher affinity) and one that was expected not to be related to them (lower affinity). The order of the problems was varied in the different sessions and they were given the following instructions (Fig. 1):

The time available to solve each problem was established in 40 min, since it has been proved that the frequency of idea production, during the creative stage of design, is constant during the first 60 min (Howard et al. 2008). Similar studies use times within the range of 30–60 min for this kind of conceptual problem-solving experiences, like the ones carried out by Chulvi et al. (2020) (30 min), García-García et al. (2019) (30 min), Viswanathan and Linsey (2012) (40 min),

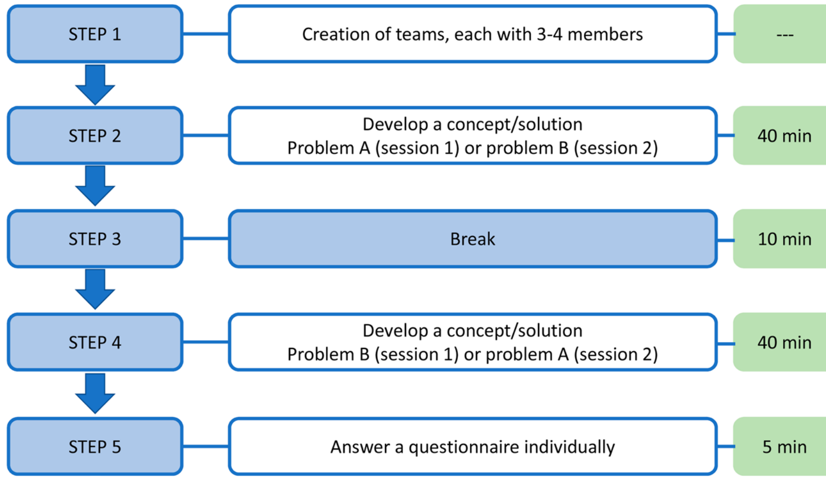


Fig. 1 Experiment steps

Sipilä and Perttula (2006) (40 min) or López-Mesa et al. (2011) (45 min), between many others.

The novice designers had to face the problem-solving design stage, which consists in activities such as generation, evaluation and selection of the final proposal for further development (Chakrabarti 2003). During this process, the participants could generate more than one alternative to solve the design problem, but, at the end of the experience, they had to choose the option they considered that was most fitted with the problem proposal. The problems asked were:

Problem A (expected higher affinity): Develop a novel concept for an element to be used to carry personal items, taking into account the considerations of the circular economy.

Problem B (expected no affinity): Develop a novel concept for a trolley for porters and caretakers, which can be adapted according to what has to be carried, taking into account the considerations of the circular economy.

The students were given 40 min to solve each of the problems. When the time was up, they had to deliver a conceptual solution to the problem on an A3-size sheet of paper. In addition to the A3 sheet of paper, the participants also had A4-size sheets of paper, drawing material and computers connected to the internet to search for information, if they wished to do so.

Between solving one problem and starting on the next, they were allowed a 10-min break. After finishing work on the two problems, the participants had to answer a Likert scale-based questionnaire to indicate their level of motivation for each of the products to be designed, how relevant it was for them, their affinity for the product and the level of knowledge they considered they had about it (Fig. 2). Self-reporting is commonly used in different studies as, for example, in Grewal et al. (2019) or Kunrath et al. (2020). Tracey and Hutchinson (2016) highlight the importance of the awareness of the self-as-designer. Self-assessment is usually done by ranking competences with the help of the extremes of a scale. Using only this type of self-evaluation, with Likert scales, can lead to a biased self-perception whether the study is long-lasting, due to the effect of possible social changes experimented by the respondents (Ward et al. 2002), but this effect is not occurring in an occasional activity framed in half a day-period of time, as it is the case in this work. On the other hand, a Likert scale (Likert 1932)

	Product A: carrying objects					Product B: trolley for caretakers				
	Low		Medium		High	Low		Medium		High
Your knowledge of the product is:										
The relevance of this product for you is:										
The motivation you feel about this product is:										
The affinity you feel for this product is:										

Fig. 2 Questionnaire

is a psychometric response scale used to obtain the preferences of the participants, in terms of agreement with a statement or a set of statements. These scales are non-comparative and unidimensional and the respondents indicate the level of agreement with the statements proposed through an ordinal scale (Bertram 2007). Likert scales allow measuring the attitude of the respondent in a scientifically accepted and validated manner (Joshi et al. 2015). In the current research the questionnaire has been set up with emoticons, which is eventually used in Likert questionnaires (Guinard, 2000; Swaney-Stueve, 2018; Alismail and Zhang, 2020). The two most extreme questionnaire scores or the use of emoticons might depend on the understanding of each participant. As Alismail and Zhang (2020) point in their work, these factors could have caused a biased result but all on the same scale, so this doesn't affect the results, considering that in their case they used only a qualitative Likert scale, while in the present work it has been added a numerical scale. They also said in their study that the use of emoticons makes the questionnaire more friendly for the respondents. To reduce this biasing effect, the questionnaire together with the terms employed were explained to the participants at the beginning of the experience to ensure that they understood the questions. The terms employed in the questionnaire were verbally explained to the participants just before starting the step 5 (Fig. 1).

3.2 Design results assessment

The evaluations of the 22 concepts were performed by two experts, a last-year PhD student with both professional and research experience in the field of circular design and creative design and a PhD with experience in the field of engineering design and with previous knowledge about the problems solved and the evaluation methods applied. The Coefficient of Intraclass Correlation has been calculated for the two evaluations.

3.2.1 Novelty assessment

Novelty was assessed using the SAPPhIRE method (which stands for State-Action-Part-Phenomenon-Input-oRgan-Effect), proposed by (Chakrabarti et al. 2005). This model has already been empirically validated, the conclusion being that it indeed corresponds to the way engineers design technical concepts (Ranjan et al. 2012; Srinivasan and Chakrabarti 2010). It has been formally evaluated in terms of the level of agreement between the results provided by the model and the degree of novelty perceived by experienced designers for the same products (Sarkar 2007; Sarkar and Chakrabarti 2007). Figure 3 shows the hierarchical scheme of the different levels of abstraction that make up the SAPPhIRE model. In this model, Action is the highest level of

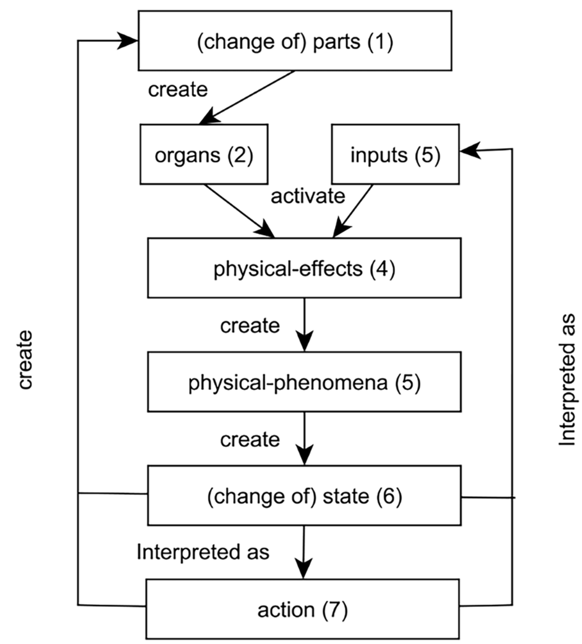


Fig. 3 The SAPPhIRE model (Srinivasan and Chakrabarti 2010)

abstraction, understood as an interpretation of a change of state or the creation of an input. State refers to the attributes and their values that define the properties of a particular system at a given instant in time during its operation. Physical phenomena refers to the set of potential changes associated with a given Physical effect, which in turn is the natural law that governs that change. Organs are the structural contexts needed to activate a Physical effect, while Parts are the physical components that make up an Organ. Thus, Parts are needed to create Organs, which (together with the necessary inputs) activate the Physical effects needed to create a Physical phenomenon that generates a State change. This latter, in turn, will then be interpreted as an Action or input that is going to create or activate a Part.

To identify the level of relative novelty in products, the highest level (very high novelty) corresponds to those that satisfy a function or Action for the first time; a change in State change or input represents the next level of novelty (high novelty); a lower level of novelty (medium novelty) refers to a change in Physical phenomena or Physical effect; and the lowest level (low novelty) comprises those systems in which one product differs from others only by changes in its Organs or Parts. The novelty assessment comes up by the comparison of the proposal with a standard solution, to determine in which levels there are changes.

The standard solution has been established as an abstract concept. For the carrying element, it consists of a medium-sized fabric rucksack with two compartments—the main one and a smaller one on the outside—with two straps allowing it to be carried by the user. Both compartments can be closed with a zip. The parts established for the standard solution are the most common for this specific type of transport element, what means that the differences between the solutions evaluated are not relevant for the comparison of the concepts with the standard element. SAPPhIRE model for the standard solutions is shown in Tables 2 and 3, together with the calculation of novelty value. So, for example, the evaluation of the concept shown in Fig. 4 will result as seen in Table 2. Here, the functions that are more novel than the standard solution are highlighted in green. So, according to the SAPPhIRE scale, this solution presents a low novelty level, since their highest changes are presented at the organ level, even though it presents several changes at this level.

The standard solution for the transport trolley is, as in the previous case, an abstract proposal. It consists of a surface fitted with a non-slip rubber covering on which to place the load, a one-piece folding handle and four wheels. In this case, the evaluation of the concept presented in Fig. 5 is represented in Table 3. The functions that are more novel than the standard solution are highlighted in green and in red the missing functions that are in the standard solution but not in the proposal.

3.2.2 Circularity assessment

The circularity of each of the proposals was assessed using the tool provided by the Circular Economy Toolkit (Evans and Bocken 2013). This free tool (Fig. 6) allows quantifying the 33 parameters, with three possible scores divided into 7 categories related to the CE and the "cradle-to-cradle approach", which offers information on how to decrease the amount of waste generated and to reduce the use of materials, as well as on the potential areas for improvement of the product or firm (Evans and Bocken 2013; Miedzinski et al. 2016). Each of the parameters assessed with the tool was given a score of 0 (high), 1 (medium) or 2 (low), as appropriate for each proposal, according to the drawings and the explanatory texts that the designers have expressed in the solution sheets. For example, in Fig. 4, as in the concept solution is seen that the product doesn't use scarce materials, this parameter in the tool has a score of 0 and, as there is not a repair service for the product (or, at least, is not indicated in the solution), the score for this parameter is 2. As regarding the modular parts, as there are few, but could be more modular parts, the score is 1.

A general score was obtained by adding up the scores on each of the aspects, thereby yielding minimum and maximum scores for the proposal of 0 and 66, respectively. Being 0 the best score possible (the more circular) and 66 the worst score possible (the less circular), which is, the lower the score, the more circular is the solution.

Following the same examples as in case of novelty assessment, Tables 4 and 5 show the evaluation of concepts of Figs. 4 and 5, respectively.

3.3 Data analysis

All the statistical analyses were performed with the software SPSS, PASW Statistics version 25 (IBM Corporation). The parameters Novelty, Circularity, Motivation, Knowledge, Relevance and Affinity were treated as variables in the following analyses, firstly assuming that they are independent. After study their relationship they have been treated as a dependent, analysing their relationship with novelty and circularity (two analysis by separate) through multivariate regression, with the limitation of having a small sample size.

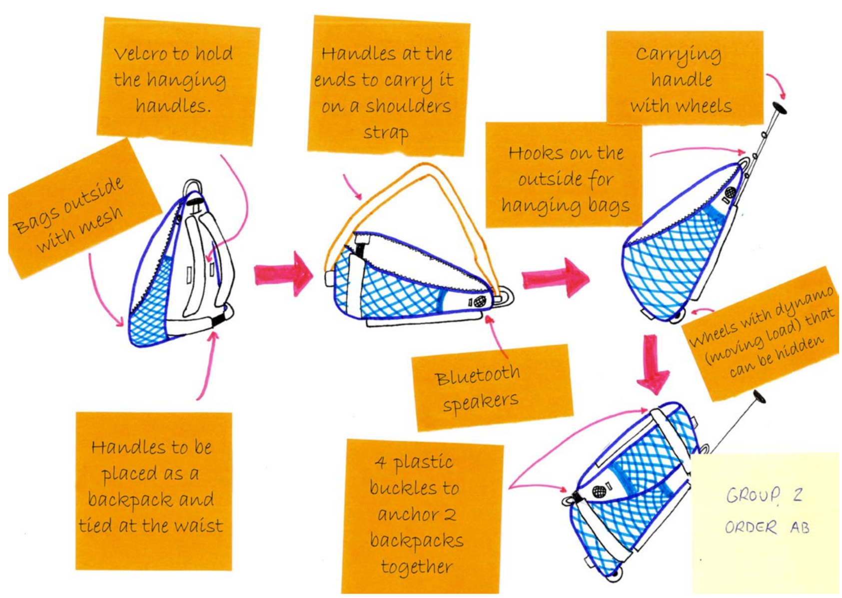


Fig. 4 Design solution 2A

Table. 2 SAPPhIRE evaluation of concept solution for the carrying element

	Standard solution	Desing solution 2a
Action	Carrying objects	=
State change	Solid	=
Phenomenon	Contact between rucksack/case and object	=
Effect	The rucksack/case holds the object	=
Organ 1 (system where things are carried)	Bags	Bags, **net**
Organ 2 (system for holding by a human)	Straps (2)	straps (2), **shoulder strap, waist strap, trolley, top handle**
Organ 3 (closure system)	Closure by means of zips	=
Organ 4 (rucksack transport system)		**Trolley**
Organ 5 (extra functions)		**speakers, dynamo wheels, accessory hangers**
Part 1_1	Large bag	large bag **with hanger (2)**
Part 1_2	Small bag	small bag (net) **(4)**
Part 2_1	Straps (2)	straps (2) **With Velcro** **Shoulder strap with hangers** **Top hanger** **Waist strap** **Trolley strap**
Part 3_1	Zip	=
Part 3_2	Zip closure	=
Part 4_1		**Trolley structure**
Part 4_2		**Wheels (2)**
Part 5_1		**Speakers (2)**
Part 5_2		**Wheels dynamo (2)**
Part 5_3		**Hangers (3)**
SUM "action"		9
SUM "state change"		22
SUM "phenomenon"		
SUM "effects"		
SUM "organs"		
SUM "parts"		

After calculating the statistical indicators for all the parameters results and to analyse how the intrinsic factors of each participant (Motivation, Knowledge, Relevance and Affinity) interact, a linear regression analysis was performed, as said before, to compare the *p* values obtained, followed by a Spearman correlation test determining the size of the correlation. On the other hand, to see how the intrinsic factors affect circularity, a multivariate regression was performed followed by a Spearman correlation. To see how these factors affect novelty, an ordinal multivariate regression was carried out, followed by the Kendall's Tau correlation. For this purpose, the data were processed according to the working groups, not the individuals, so the statistical indicators were also calculated for the group results. Therefore, Novelty and Circularity were compared by separate with Motivation, Knowledge, Relevance, and Affinity, after determining that the four factors were dependent to each other Table 6, shows a summary of the statistical analysis carried out.

4 Results

4.1 Novelty and circularity of the design outcomes

As part of the experiment, two proposals were generated by each of the work groups, one for the element for carrying personal items (rucksacks or cases) and the other for caretakers' trolleys. The proposals can be seen in the following Tables 7 and 8. The results of novelty can be seen in Table 9 and the circularity results in Table 10.

As mentioned in sub-Sect. 3.2, two evaluators experts in the field have also assessed the design results. After this, the coefficient of intraclass correlation (Bland and Altman 1996) has been calculated, resulting r = 0.961 for novelty and r = 0.862 for circularity. Therefore, there is a large correlation between the two groups of results, which gives robustness to the evaluation performed.

Table. 3 SAPPhIRE evaluation of concept solution for the transport trolley

	Standard solution	Desing solution 3b
Action	Carrying objects	=
State change	Solid	=
Phenomenon	Contact between trolley and object	=
Effect	The trolley holds objects	=
Organ 1 (system where things are transported)	Platform	**Platform (2)** **Modules (2)**
Organ 2 (system for holding by a human)	Whole handle	**Adjustable handle**
Organ 3 (transport system)	Wheels	=
Organ 4 (system for folding the handle)	Pedal	**Not foldable**
Organ 5 (movement system of the platforms)		**Manual**
Organ 6 (extra functions)		**Brake, proximity sensor, electrical support**
Part 1_1 Part 1_2 Part 1_3	base of the platform non-slip surface	**Base of the platform (2)** **There isn't** **Modules to extend the surface (2)**
Part 2_1	whole handle	**Adjustable telescopic handle**
Part 3_1	wheels (4)	**=**
Part 4_1 Part 4_2	pedal for activating the folding mechanism elements of the folding system	**Not foldable handle** **Not foldable handle**
Part 5_1		**Telescopic structure**
Part 6_1 Part 6_2 Part 6_3		**Brake** **Proximity sensor** **Electronic components**
SUMA "action" SUMA "state change" SUMA "phenomenon" SUMA "effects" SUMA "organs" SUMA "parts"		7 5

4.2 Intrinsic personal factors results

The results obtained in the motivation questionnaire are shown below. As can be seen in Tables 11 and 12, values between 1 (Low) and 5 (High) were collected for each of the problems posed and for each of the aspects that were enquired about in the questionnaire.

Figure 7 shows the scores obtained in each of the parameters, both for problem A (personal carrying element) and problem B (caretaker's trolley). In general terms, the personal intrinsic factors obtained clearly higher scores in problem A.

Analysing how the intrinsic personal factors vary according to the problem it is obtained that, in the case of motivation, it can be seen how in problem A, which was set as a higher affinity problem, the scores are concentrated between 3 and 5, in contrast to problem B, where they are concentrated between 2 and 4. These results, thus, show that the most motivating problem was the one for which the participants in the experiment were expected to have greater affinity, that is, that the most motivating problem was problem A (personal carrying element).

As regards knowledge, the participants in the experiment stated that they were more knowledgeable about problem A (personal carrying element) than about problem B (caretaker's trolley), with problem A achieving scores mostly between 3 and 4 and, problem B, between 2 and 3.

For the participants in the experiment, problem A was notably more relevant than problem B. For problem A, most of the scores were between 4 and 5 and, for problem B, most of the scores were between 2 and 3.

Finally, problem A was also considered to have a greater degree of affinity for the participants, with scores concentrated between 4 and 5, versus the scores mostly between 2 and 3 for problem B. This result coincides with the initial consideration, that problem A was expected to present higher affinity than problem B.

4.3 Relationship between the personal intrinsic factors

To determine whether there is some kind of interaction among the different personal factors analysed, a linear regression analysis was performed with the data obtained.

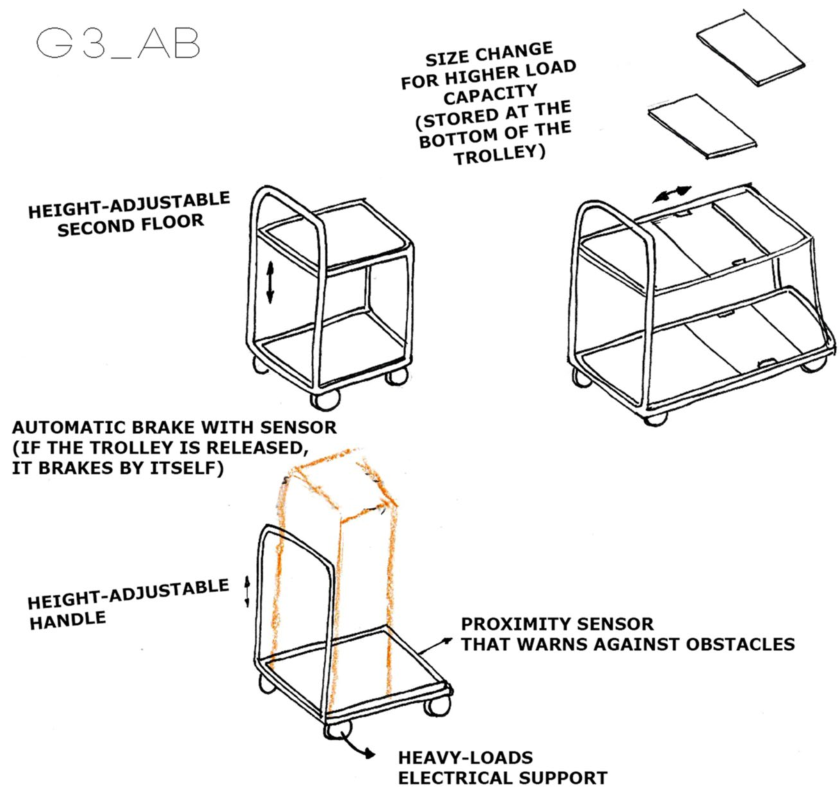


Fig. 5 Design solution 3B

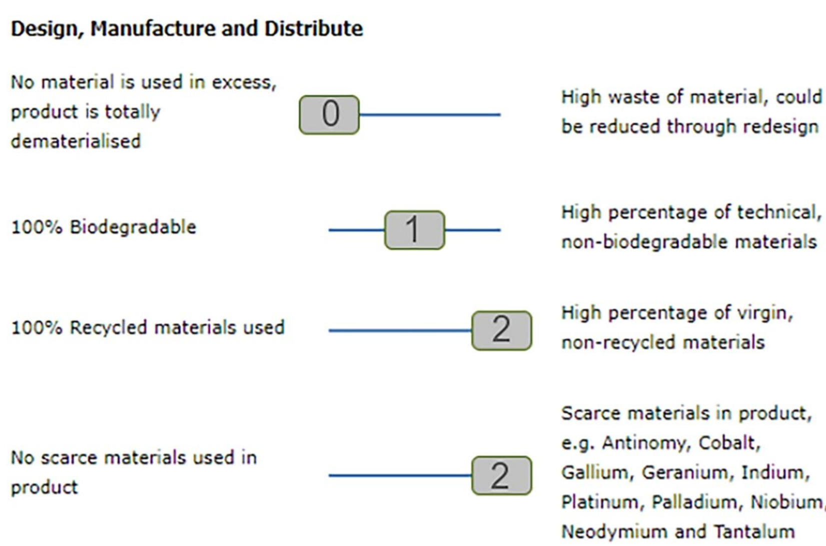


Fig. 6 Circular Economy Toolkit adapted from http://circulareconomytoolkit.org/Assessmenttool.html

This analysis allows seeing if the relationships between knowledge/relevance/affinity and motivation for the design problem and between knowledge held about the problem and motivation/relevance/affinity. The graphs in Fig. 8 shows the relationship between the different factors analysed. To measure the correlation size (Table 13) among the different groups that were studied, *Spearman correlation* was calculated. The numerical results are shown in Table 14

The first analysis tests how motivation could be influenced by the knowledge reportedly held about the problem. In this case the *p value* obtained in carrying out the statistical test is lower than the critical value and therefore the result is significant. As can be seen in Fig. 8, .motivation increases at the same rate as declared knowledge. The result of the *Spearman correlation* test is 0.615, and hence the correlation is good.

Table. 4 Punctuation of 2A solution

Question	Punct. 2A	Question	Punct. 2A	Question	Punct. 2A
Product dematerialised vs. Waste of material	1	Repair service offered vs. No repair service offered	2	Difficult to disassemble vs. Easy to disassemble	2
100% biodegradable vs. Non-biodegradable	1	Difficult access to internal workings vs. Easy access to internal workings	2	Damage to the product when disassemble vs. No damage when disassemble	2
100% recycled vs. Virgin materials	2	Complex workings vs. Simple workings	1	Impossible to identify parts disassembled vs. Easy to identify parts disassembled	2
No scarce materials vs. Scarce materials	0	Components no standardised vs. components standardised	1	No modular parts vs. Many modular parts	1
Highly eco-efficient materials vs. Poor ecoefficiency materials	1	Difficult to find fault vs. Easy to find fault	2	Impossible to upgrade parts vs. Possible to upgrade parts	2
No toxic materials vs. Excess toxic materials	0	No market for second hand vs. good market for second hand	1	Many mechanical connections vs. Few mechanical connections	2
Zero waste factory vs. Significant waste from factory	1	Second-hand sales already offered vs. No second-hand sales offered	2	Many tools required to disassemble vs. Few tools required to disassemble	2
No product failures vs. Frequent product failures	2	Very long lifetime vs. short lifetime	2	No market to sell products as a service vs. Good market to sell products as a service	1
Long lifetime vs. Short lifetime	1	Expensive remanufacturing costs vs. Cheap remanufacturing costs	1	All products already sold as a service vs. No products sold as a service	2
Product uses minimum power vs. Product is resource wasteful	0	Expensive collection costs vs. Cheap collection costs	2	Few material combinations vs. High number of material combinations	0
Cost of repair outweighs cost of product vs, cost to repair is small	1	All products are returned vs. No refurbishing currently undertaken	2	No encased materials vs. many encased materials	1

The second analysis tests how motivation could vary due to the affinity with the problem. The *p value* obtained in carrying out the statistical test is lower than the critical value and therefore the result is significant. As can be seen in Fig. 8, the effect is positive, that is to say, motivation increases with greater affinity. The result of *Spearman correlation* is 0.653, and hence the correlation is good.

The next analysis tests how the perceived relevance of the problem could change the motivation that is felt towards it. In this case the *p value* obtained is also below the critical value and the result is therefore significant. As can be seen in Fig. 8, and as in the previous cases, the effect is positive, that is, the more relevant the problem is perceived to be, the more motivation increases. The result of *Spearman correlation* is 0.557, and hence the correlation is moderate.

The next analysis was performed to test how declared knowledge about the problem could change affinity with that problem. The *p value* obtained is below the critical value and hence the result is significant. As can be seen in Fig. 8, the effect is positive, that is to say, affinity increases with the perception of having greater knowledge. The result of *Spearman correlation* is 0.589, and hence in this case the correlation is also moderate.

Another analysis was performed to determine how the perceived knowledge about the problem affects the relevance it is seen to have. The *p value* obtained in carrying out the statistical test is lower than the critical value and therefore the result is significant. As can be seen in Fig. 8, the effect in this last case is also positive, that is, the relevance granted to a design problem increases along with the perception of having greater knowledge about it. The result of *Spearman correlation* is 0.683, and hence the correlation is good.

Lastly, has been determined how affinity for the problem interacts with the perceived relevance. The result shows a *p value* of 3.0682E-15, what means that the interaction is significant, the affinity makes to vary the perceived relevance for the problem. Relevance increases with affinity in a positive way, with a Spearman correlation value of 0.777 (good correlation). This can be also seen in Fig. 8.

After performing the statistical analyses of the results, there are several issues to highlight. The first of them is the participants' strong preference for design A over design B. In this sense, it has been observed that 24 individuals were more motivated by problem A compared to only 6 who were more motivated by B; 25 of them said they had

Table. 5 Punctuation of 3B solution

Question	Punct. 3B	Question	Punct. 3B	Question	Punct. 3B
Product dematerialised vs. Waste of material	1	Repair service offered vs. No repair service offered	2	Difficult to disassemble vs. Easy to disassemble	2
100% biodegradable vs. Non-biodegradable	2	Difficult access to internal workings vs. Easy access to internal workings	2	Damage to the product when disassemble vs. No damage when disassemble	2
100% recycled vs. Virgin materials	2	Complex workings vs. Simple workings	2	Impossible to identify parts disassembled vs. Easy to identify parts disassembled	2
No scarce materials vs. Scarce materials	1	Components no standardised vs. components standardised	1	No modular parts vs. Many modular parts	2
Highly eco-efficient materials vs. Poor ecoefficiency materials	1	Difficult to find fault vs. Easy to find fault	2	Impossible to upgrade parts vs. Possible to upgrade parts	1
No toxic materials vs. Excess toxic materials	0	No market for second hand vs. good market for second hand	1	Many mechanical connections vs. Few mechanical connections	1
Zero waste factory vs. Significant waste from factory	0	Second-hand sales already offered vs. No second-hand sales offered	2	Many tools required to disassemble vs. Few tools required to disassemble	1
No product failures vs. Frequent product failures	1	Very long lifetime vs. short lifetime	1	No market to sell products as a service vs. Good market to sell products as a service	2
Long lifetime vs. Short lifetime	1	Expensive remanufacturing costs vs. Cheap remanufacturing costs	0	All products already sold as a service vs. No products sold as a service	2
Product uses minimum power vs. Product is resource wasteful	1	Expensive collection costs vs. Cheap collection costs	1	Few material combinations vs. High number of material combinations	0
Cost of repair outweighs cost of product vs, cost to repair is small	1	All products are returned vs. No refurbishing currently undertaken	1	No encased materials vs. many encased materials	0

Table. 6 Statistical analysis summary

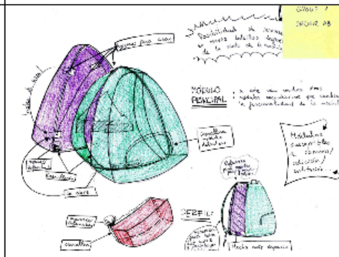
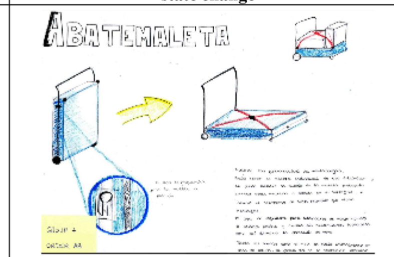
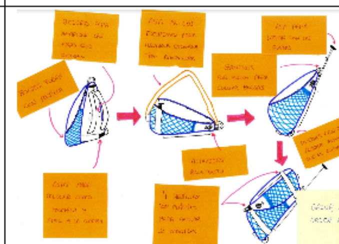
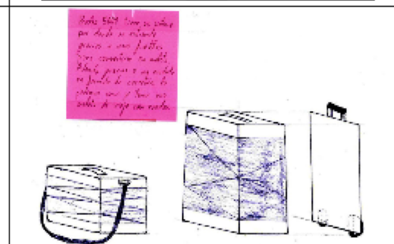
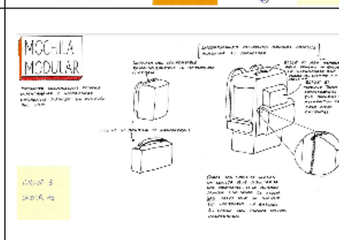
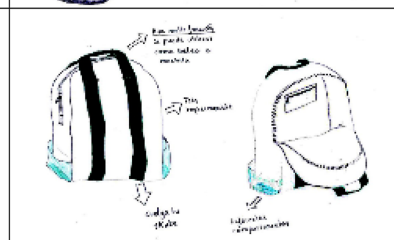
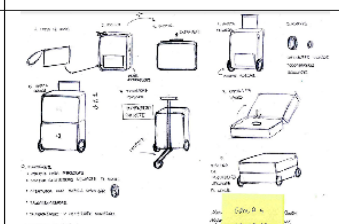
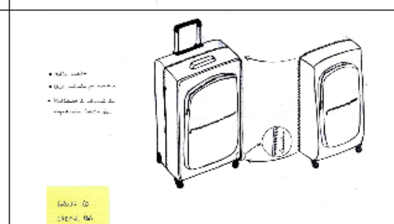
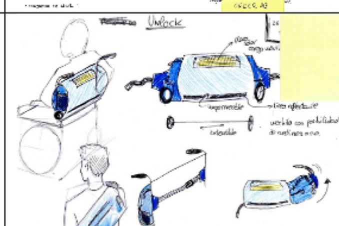
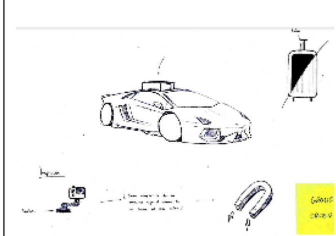
Analysis	Statistic method	Correlation test	Data used (grouped or individual)
Statistical indicators	–	–	Both
Interaction between personal intrinsic factors	Linear regression	Spearman correlation	Individual
Agreement between the two evaluators	–	Coefficient of intraclass correlation	–
How the intrinsic factors affect circularity	Multivariate regression	Spearman correlation	Grouped
How the intrinsic factors affect novelty	Ordinal multivariate regression	Kendall's Tau correlation	Grouped

greater knowledge about topic A versus only 2 in the case of B; problem A is more relevant for 31 of the students compared to only 3 who see B as more relevant; and 30 of the participants claimed they felt greater affinity for the topic in problem A than for B, which was only the case with 1 student. This marked difference can be seen in the analyses performed in the previous point, which show that there is a significant relationship among all the intrinsic factors. The trend is also clearly observable in Fig. 8.

4.4 Personal factors results by workgroup

Since the design results were generated by group, the analysis of the relationship between circularity and novelty with the personal intrinsic factors has been carried out with the data obtained for each group instead of the individual data. The statistic values from these team results can be seen in Tables 15 and 16.

Table. 7 Rucksacks conceptual proposals

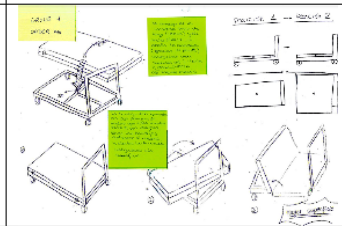
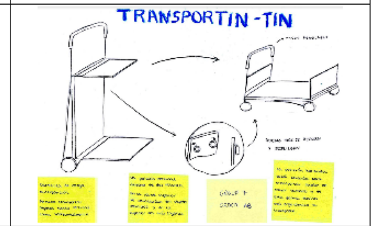
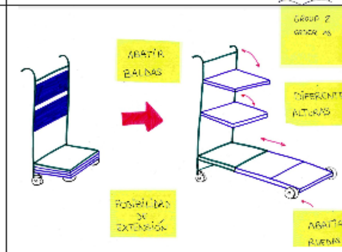
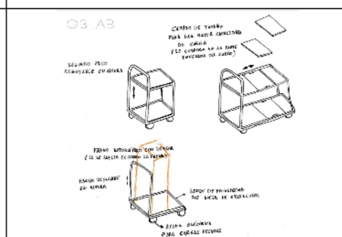
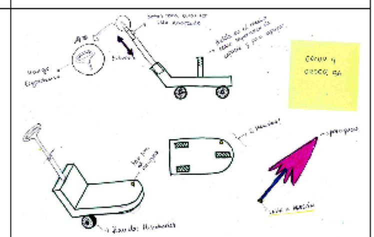
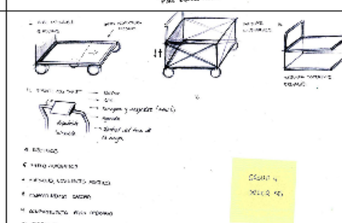
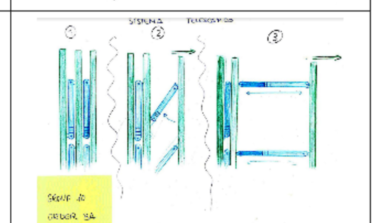
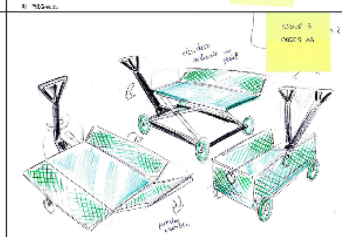
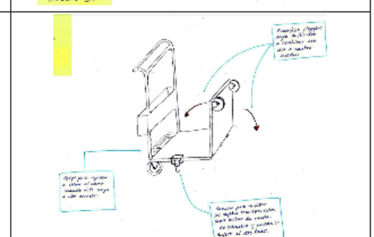
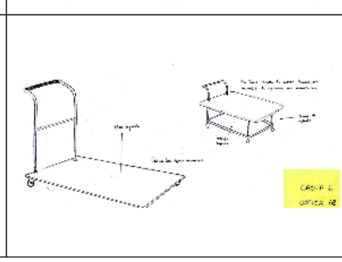
DESIGN SOLUTION	DESCRIPTION	SUM "action"	SUM "state change"
1A		7A	
2A		8A	
3A		9A	
4A		10A	
5A		11A	
6A			

4.5 Relationship between circularity and the personal intrinsic factors

The circularity assessment, has been carried out with the group results, as said before. In Tables 17 and 18 the numerical circularity results, grouped by workgroups.

To check if the circularity of the proposals could vary due to the personal intrinsic factors, a multivariate regression was performed. Followed by Pearson's correlation calculation, which values are explained in Table 19. The results of the analysis are shown in Table 20.

Table. 8 Trolleys conceptual proposals

DESIGN SOLUTION	DESCRIPTION	DESIGN SOLUTION	DESCRIPTION
1B		**7B**	
2B		**8B**	
3B		**9B**	
4B		**10B**	
5B		**11B**	
6B			

As it can be seen in Table 20 and Fig. 9, the comparison between all the personal factors and circularity results is non-significant with *p* values notably bigger than 0.05. The Pearson's correlation indicates a small positive correlation for the four factors, being all the coefficients lower than 0.3.

This smaller sample could be a limitation when calculating an interaction between variables, since it could be possible that this interaction is not detected. Maybe, due to this, the effect of the personal factors on circularity could be bigger than what the results show. Only with a large sample size this interaction could be determined with more robustness. Even with this limitation, since there are no other studies analysing the interaction between circularity and the four personal factors studied, this work offers a first insight into

Table 9 Novelty results

Design solution	Sum "action"	Sum "state change"	Sum "phenomenon"	Sum "effects"	Sum "organs"	Sum "parts"	Rank
1A						2	**12th**
2A					9	22	**4th**
3A					5	13	**6th**
4A	2		1	2	13	13	**2nd**
5A					7	10	**5th**
6A			1	1	1	4	**3rd**
7A	2		2	2	4	5	**1st**
8A					4	5	**9th**
9A					3	4	**10th**
10A					1	8	**11th**
11A					4	8	**8th**
1B					1	3	**11th**
2B					6	3	**5th**
3B					7	5	**3rd**
4B	1		1	1	8	7	**1st**
5B					2	4	**8th**
6B					3	1	**7th**
7B					2	3	**9th**
8B					2	1	**10th**
9B					7	5	**3rd**
10B					7	14	**2nd**
11B					4	3	**6th**

Final novelty values are highlighted in bold

Table. 10 Circularity results

Design solution	Score	Design solution	Score
1A	40	1B	40
2A	45	2B	39
3A	47	3B	41
4A	43	4B	45
5A	41	5B	40
6A	36	6B	42
7A	42	7B	47
8A	40	8B	40
9A	41	9B	46
10A	38	10B	34
11A	43	11B	42

Table. 11 Numerical results, carrying element problem

N = 35	Motivation	Knowledge	Relevance	Affinity
Mean	4.09	3.83	4.37	4.26
Maximum	6	5	5	5
Minimum	2	3	2	3
Std. Deviation	0.887	0.664	0.843	0.741
Variance	0.787	0.440	0.711	0.550

Table. 12 Numerical results, caretaker's trolley problem

N = 35	Motivation	Knowledge	Relevance	Affinity
Mean	3.17	2.66	2.57	2.57
Maximum	5	5	5	5
Minimum	1	1	1	1
Std. Deviation	1.014	0.968	1.037	1.008
Variance	1.029	0.938	1.076	1.017

the effect of motivation, knowledge about the problem, relevance and affinity on circularity (and of novelty in the next sub-section).

4.6 Relationship between novelty and the personal intrinsic factors

After obtaining the order of the novelty of the proposals, which can be seen in Table 9, an analysis was performed to examine the relationship between the novelty obtained and the aspects that were asked about in the motivation questionnaire: knowledge, relevance, affinity and motivation. To do so, an ordinal multivariate regression analysis was applied,

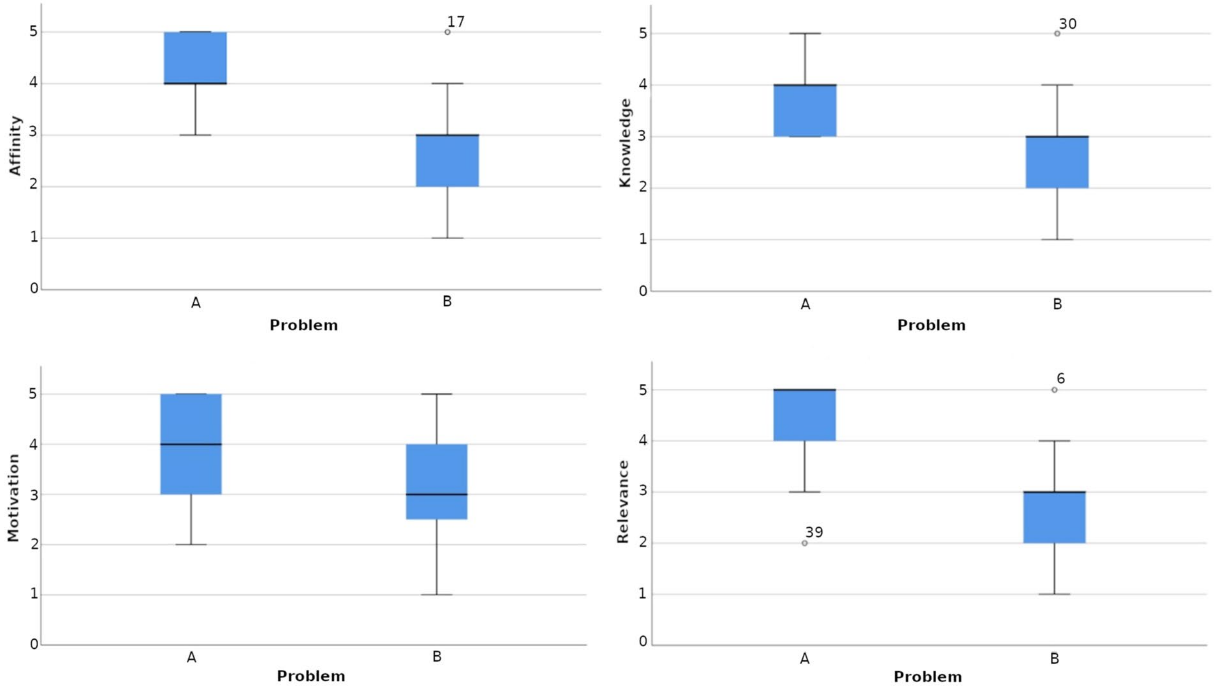


Fig. 7 Comparison of the degree of the personal intrinsic factors between problem A and problem B

Table. 13 Meaning of spearman correlation values

Value	Correlation size
Below 0.2	Very low
Between 0.2 and 0.4	Low
Between 0.4 and 0.6	Moderate
Between 0.6 and 0.8	Good
Above 0.8	Very good

which result is shown in Table 21, in this table is also shown the R-Square value, to give reliability to the analysis.

As it can be seen in Table 21, the correlation between novelty and the personal factors is significant, what means that the novelty of the results studied could be conditioned by the self-reported value for the personal intrinsic factors of the participants. It is indicated by a p value = 1,4834E-13. The Cox and Snell coefficient ($R^2_{cox} = 0.992$) indicates a large interaction between variables.

Kendall's Tau (Table 22) was also calculated to determine the size of the correlation between each personal factor and novelty and the result is a small positive correlation with values about 0.1 and 0.2 in all the factors (Table 23). The cause of this could be the small sample size. This difference between correlations (personal factors individual as opposed to grouped personal factors) could be also caused by the interaction between the four intrinsic personal factors.

Figure 10 depicts the relationship between the novelty of the results and motivation, knowledge, relevance and affinity. As it can be seen, the correlation is not so strong, but novelty increases significantly with the intrinsic personal factors

Although the results show some dispersion, this is mainly due to the fact that the novelty values are ordinal. The trend lines added to the graphs reveals a tendency to

Table. 14 Intrinsic personal factors result

N = 70; $p_{critic} = .05$	p value	95% Confidence interval	Spearman correlation	Correlation size
Motivation vs. Knowledge	5.2506E-9	(0.458; 0.849)	0.615	Good
Motivation vs. Affinity	2.1229E-11	(0.450; 0.749)	0.653	Good
Motivation vs Relevance	1.1452E-7	(0.312; 0.629)	0.557	Moderate
Knowledge vs. Affinity	2.3487E-8	(0.345; 0.664)	0.589	Moderate
Knowledge vs. Relevance	3.7824E-11	(0.400; 0.672)	0.683	Good
Affinity vs. Relevance	3.0682E-15	(0.666; 0.992)	0.777	Good

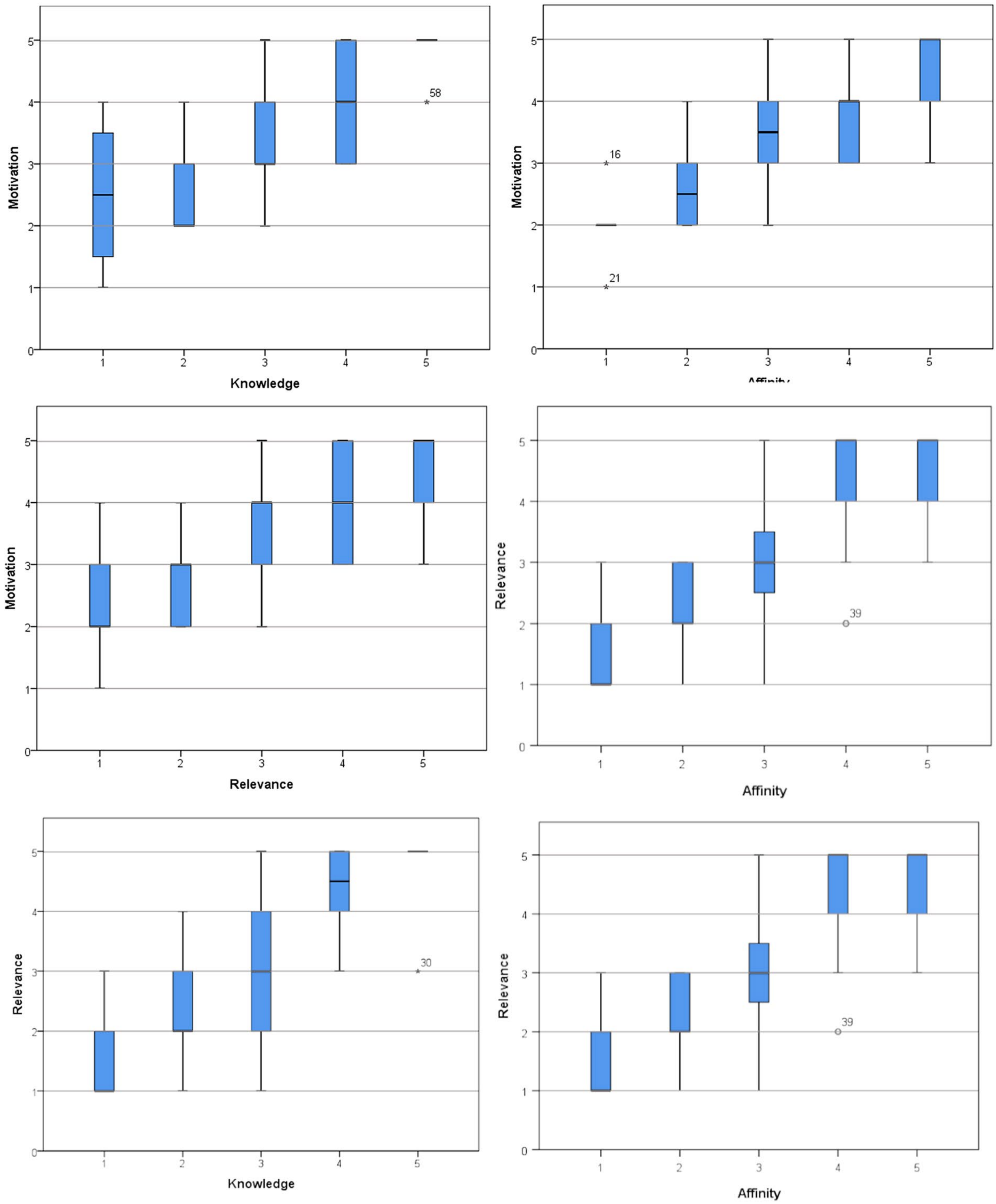


Fig. 8 Relationship between the personal intrinsic factors

improve the novelty results as the personal intrinsic factors increase. As they have been found to be dependent on each other, it seems reasonable that this trend occurs in all four factors. It can be appreciated that this trend is more pronounced in the case of perceived knowledge than in the rest of the cases.

Table. 15 Numerical results by group, carrying element problem

N = 11	Motivation	Knowledge	Relevance	Affinity
Mean	4.007	3.795	4.318	4.205
Maximum	5.00	4.50	5.00	5.00
Minimum	3.33	3.00	3.00	3.00
Std. Deviation	0.581	0.482	0.655	0.601
Variance	0.338	0.232	0.429	0.362

Table. 16 Numerical results by group, caretaker's trolley problem

N = 11	Motivation	Knowledge	Relevance	Affinity
Mean	3.12	2.63	2.56	2.55
Maximum	4.67	3.25	3.67	4.00
Minimum	1.50	2.00	1.50	1.00
Std. Deviation	0.798	0.429	0.631	0.785
Variance	0.637	0.184	0.398	0.616

Table. 17 Numerical results by group, carrying element problem

N = 11	Circularity
Mean	41.45
Maximum	47.00
Minimum	36.00
Std. Deviation	3.078
Variance	9.473

Table. 18 Numerical results by group, caretaker's trolley problem

N = 11	Circularity
Mean	41.45
Maximum	47.00
Minimum	34.00
Std. Deviation	3.643
Variance	13.273

Table. 19 Meaning of Pearson Correlation values

Value	Correlation size
Between 0.1 and 0.3	Small
Between 0.3 and 0.5	Medium
Between 0.5 and 1	Large

Table. 20 Correlation between circularity and personal factors

N = 22; $p_{critic} = .05$	p value	95% Confidence interval	Pearson's Correlation	Correlation size
Circularity vs. Motivation	0.661	(− 4.024;2.619)	0.102	Small
Circularity vs. Knowledge	0.851	(− 5.352;4.464)	0.072	Small
Circularity vs. Relevance	0.669	(− 4.955;3.263)	0.105	Small
Circularity vs. Affinity	0.229	(− 1.439;5.606)	0.222	Small

5 Discussion

In the case of the results for novelty and circularity, they may have been affected by the need to average out the personal factors of the design team members. This was necessary because the concepts analysed correspond to teamwork results. Initially, more novel results are obtained for problem A and, novelty, increases with the personal aspects (motivation, knowledge, relevance and affinity), according to the ordinal multivariable regression analysis performed ($p = 1{,}4834E\text{-}13$). These results are in line with Gilson et al. (2012), who narrow down the effect of intrinsic motivation only to radical innovation cases, which are more linked to novel solutions. Nevertheless, in Fig. 10 it can be perceived that, even following the trend that the novelty increases with the personal factors, the dispersion of the results is high. As novelty is one of the main components of creativity (Sarkar and Chakrabarti 2008), the results presented extend the previous ones and run on the same line as studies that indicate that intrinsic motivation helps to achieve a more creative outcome (Amabile 1996; Gilson et al. 2012; Medeiros et al. 2017; Morosanu 2018).

As regards circularity, the effect of the analysed results seems to be the other way round: more circular results are produced in the problems with the lowest scores on personal factors. In this case, the tendency to decrease circularity when personal factors increase has not proved significant according to the multivariable regression analysis performed ($p_{motivation} = 0.661$; $p_{knowledge} = 0.851$; $p_{relevance} = 0.669$; $p_{affinity} = 0.229$). Nonetheless, previous studies point in the same direction, showing that when environmental aspects are considered as design requirements, the outcomes are more conservative, that is, less novel results (Collado-Ruiz and Ostad-Ahmad-Ghorabi 2010). In the case of circularity, if they hadn't the knowledge about the product regarding this topic, the participants searched for more information in the computers they had for this purpose, focussing more in the circularity of the results. In the run experiment, this could be the reason why circularity slightly decreases with the increment of the intrinsic factors, while novelty increases. Although results are not significative, in Fig. 9 it can be perceived that the trend lines point towards the same conclusions, circularity decreases slightly as the values of personal factors increase (remember that according to the scale used the value zero corresponds to the most circular result).

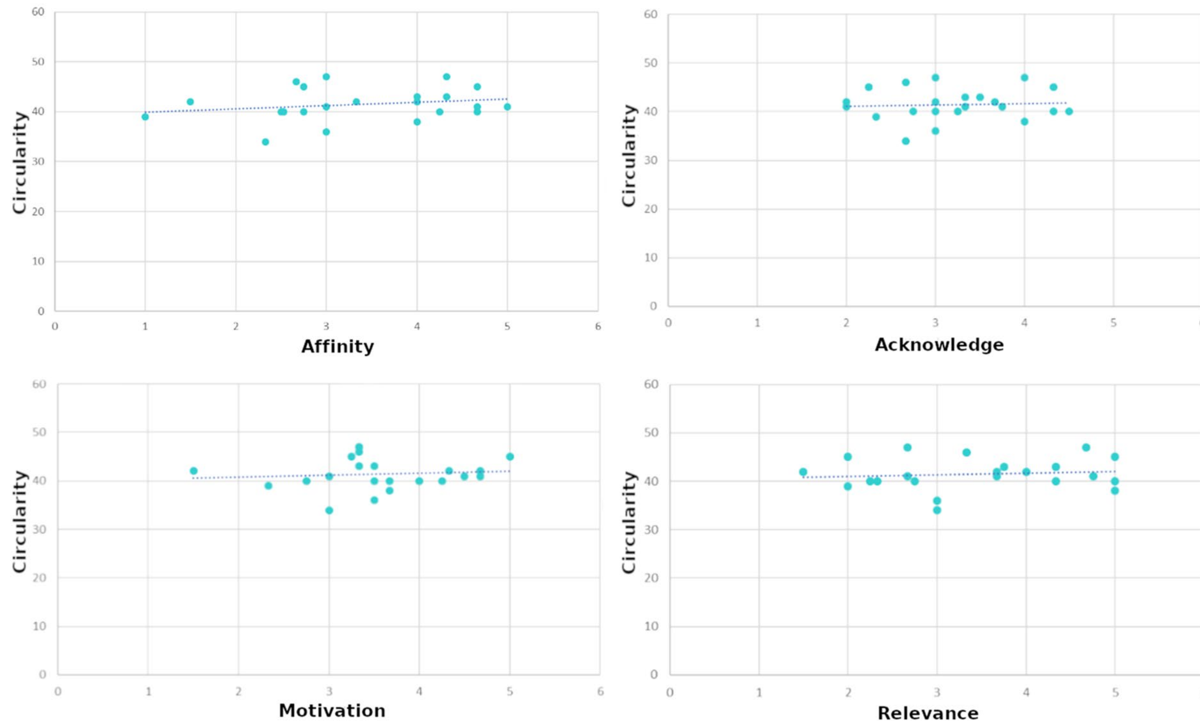


Fig. 9 Relationship between circularity and the personal intrinsic factors

Table. 21 Correlation between novelty and personal factors

df = 21; p_{critic} = .05	*p* value	R-Square (Cox and Snell)
Novelty vs. Personal intrinsic factors	1,4834E-13	0.992

Table. 22 Meaning of Kendall's Tau values

Value	Correlation size
Between 0.1 and 0.3	Small
Between 0.3 and 0.5	Medium
Between 0.5 and 1	Large

Table. 23 Correlation between novelty and personal intrinsic factors

	Kendall`s Tau	**Correlation size**
Novelty vs. Motivation	0.159	Small
Novelty vs. Knowledge	0.259	Small
Novelty vs. Relevance	0.090	Small
Novelty vs. Affinity	0.145	Small

The correlation among the intrinsic factors are in line with the work of Limberg (1998), that points that the more interested we are on the topic, the more information we seek about it. Consequently, novice designers that claimed higher motivation also had more knowledge of that topic (Spearman correlation 0.615), because they are better informed about the topic, and discrepancies between persons perception of knowledge and their actual knowledge are not unusual (Radecki and Jaccard 1995).

So, this knowledge acquired due to interest does not lead to more circular results, which seems to suggest that both types of knowledge, the acquired due to interest and the one compiled at the beginning of the task, are required to come up with good results in novelty and circularity. Allowing participants to obtain information from the internet if they wished to do so may have helped to improve the circularity results, as ignorance about a topic may lead them to search for specific information on that topic, while those who already knew about it relied on their previous knowledge to a greater extent. On the other hand, people who have overestimated their own knowledge run the risk of seeking too little information and, as a consequence, make their decisions on insufficient grounds (Radecki and Jaccard 1995), since gathering information is one of the five phases of decision-making according to Galotti (2005). This could be a reason why circularity is slightly lower when the perceived knowledge increases. This conclusion appears to be in line with the work of (Inoue et al. 2017), insomuch that searching for information could have resulted in ideas that were less diversified and unexpected, although they met the objective

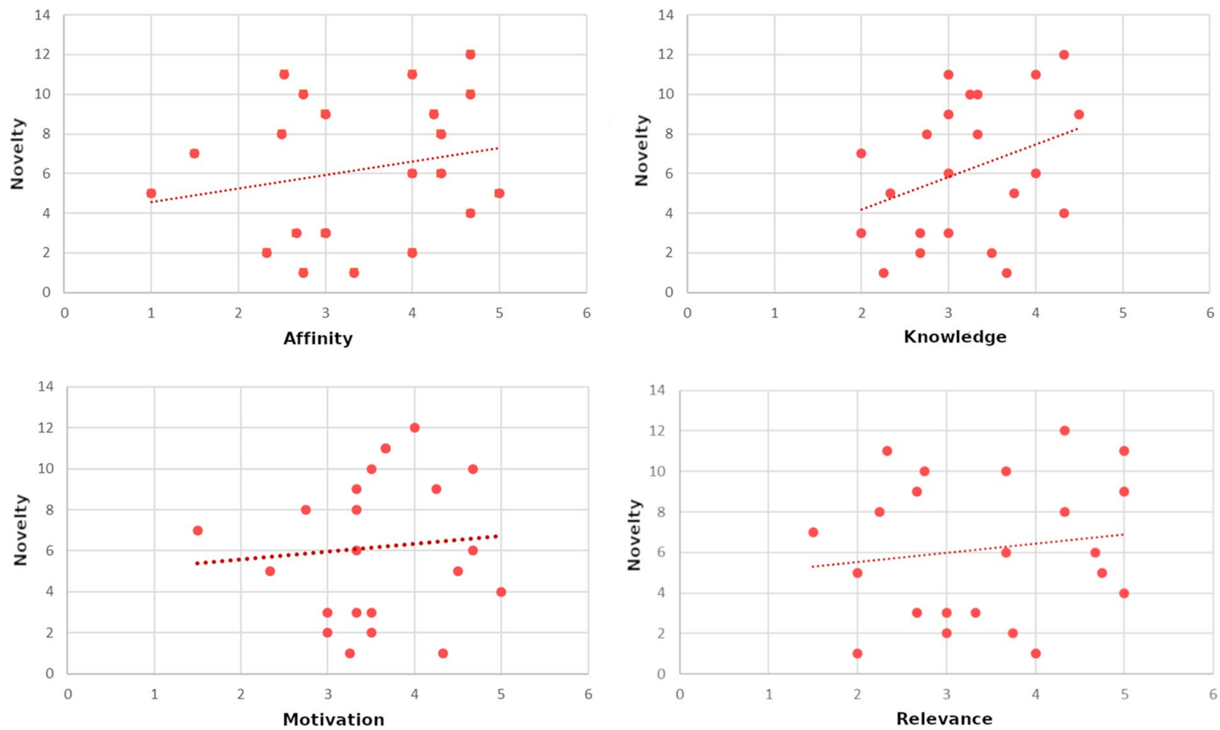


Fig. 10 Relationship between novelty and the personal intrinsic factors

of circularity more accurately. This would, in turn, be related to the work of (Ahmed et al. 2003), which relates knowledge to design results that better fit the requirements.

The results obtained may be due to the fact that a lack of knowledge implies that, because we are not familiar with everything that exists on the market, the results are not entirely novel and, on the other hand, the search focuses more on developing the elements that endow the design with, possibly, greater circularity. Moreover, the fact that designers achieve results with a higher dose of novelty when they claim to have greater knowledge about the problem may be because that greater knowledge of the problem allows them to be more novel. Indirectly, with this increasement of novelty, they largely stop working on circularity. According to Chakrabarti (2003), knowledge and the flexible processing of knowledge, understood as a support for free associations between this knowledge to create alternative outcomes, are some of the central influences on creativity. In this line, this study makes an insight into how knowledge can affect the parameters related to creativity.

6 Conclusion

This research shows the degree of novelty and circularity of the conceptual ideas proposed by 35 students organised in 11 groups of between 2 and 5 members with different degrees of knowledge, relevance, motivation and affinity. All these intrinsic factors presented positive correlations between them. This answers the last research question, referring to the possible interaction between the designer's intrinsic factors: R5—Is there correlation among the intrinsic factors: intrinsic motivation, affinity, relevance and knowledge?

Regarding the other research questions (R1 to R4), they seem to be conditioned by the correlation between personal intrinsic factors. Since all the personal factors analysed have proved to be positively correlated with each other, they show the same trends regarding the novelty and the circularity of the results analysed.

Therefore, regarding R1 "When the intrinsic motivation increases, is there a higher novelty and circularity?", the novelty of the results analysed increases with intrinsic motivation. However, the circularity of the solutions decreases with IM, but in this case not significantly. The same happens with R2 "When the level of affinity about a design problem is higher, is there a higher novelty and circularity?": it has a positive relation with novelty but slightly negative with circularity. These findings contribute to the existing knowledge about the influence of affinity in the design outcomes, since it was already known that a positive relation between the design process parameters and the affinity of the designer for the problem exists. The research questions referred to R3 "When designers perceive a design problem as more relevant, is there a higher novelty and circularity?" and R4

“When the level of knowledge about a design problem is higher, is there a higher novelty and circularity?”, as in the other cases, novelty of the results analysed increases with them, and circularity slightly decreases.

With these conclusions, we provide an answer to the research questions posed in the objective. We also fulfil our aim of expanding the knowledge we have about the relationships between the personal intrinsic factors towards a design problem and novelty and circularity, with the intention of being able to optimise decision-making so that our teams obtain improved results at design practice. In this sense, design managers could analyse the intrinsic factors about a design problem to get some idea of the design team situation about the problem and arrange the teams with the lowest or highest scores in the intrinsic factors accordingly. If there are no differences in the intrinsic factors, if the main goal is to generate novel ideas, design managers could make the design team get more knowledge about the problem and organise previous workshops that could lead to increase the intrinsic factors (relevance, affinity and intrinsic motivation) about the problem. Contrarily, when the main goal is to generate ideas with high fulfilment of the circularity requirements, the design manager should not invest additional effort to intensify the intrinsic factors. As for the occasions in which the companies seek both high novelty and high fulfilment of circularity and all the designers have similar scores for the intrinsic factors, future work is needed.

A limitation of the results is that the research was done with design groups to emulate the work at design studios, the design outcomes are at design teams’ level, while the intrinsic factors are individual. With the purpose of solving this problem, an average value of the personal factors of each team has been established to be able to analyse the results. As a result, the sample has been considerably reduced, which constitutes the greatest limitation of the study when it comes to providing solid conclusions. Therefore, in future work, it is intended to replicate the same experiment by enlarging the sample, to check whether the same tendencies presented in the current study persist. Nevertheless, the findings of this study are still valuable since they point to a first conclusion for expanding knowledge to improve the addressing of design problems according to the intrinsic personal factors of each designer and to optimise the combination of novelty and circularity in the design results.

These results are the grounding for further work, raising a new hypothesis, that the closeness to the problem (in terms of relevance, affinity, knowledge and motivation) may cause designers to stop working on circularity, looking for more novel results, while, when they feel detached from the design problem, they tend to achieve more circular results. But this hypothesis will have to be tested in future work, by analysing the time they spend on searching for information, to see if it is really confirmed. The findings also show that could be advantageous to incentive the designers to improve their motivation towards the design problem, but in this case that would be an improvement of extrinsic motivation, since the intrinsic is only the one that focuses on the specific task and the enjoyment of doing it (Zimmerman and Campillo 2003), not an external reward. It is necessary to study if the extrinsic motivation has the same effect on the results obtained as the intrinsic motivation does. All the participants in the experiment are novice designers, students in the last year of the Bachelor's Degree in Industrial Design, and it would thus be interesting to conduct further studies to see whether the same thing happens with experienced designers. On the other hand, further research will be needed to solve the problem of lower novelty when designers present low motivation, knowledge, relevance and affinity with the problem.

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