Comparing Creativity, User-experience and Communicability Linked to Digital Tools during the Fuzzy Phases of Innovation

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Abstract: Innovation is defined by a range of activities having different goals but driven by the same purpose. For example, in the ending phases, the aim will be to put forward precise concepts, while upstream of innovation, the activities are defined by the will to investigate the subject and increase the area of knowledge and concepts helpful for the conception of new products. This study takes place in the latter contexts because these are the ones where tools are the most variable and *de facto*, the least normalised. Our aim was to study user experience felt by the usage of these tools as well as their impact on creativity and ideas' communicability. To do this, we led an experimental study with 79 participants comparing four tools: pen & paper, Virtual-Reality (VR) drawing, VRCAD, and traditional CAD. Thanks to the UEQ (Laugwitz et al., 2008) and judges method of Cropley and Cropley (2008), we measured the user-exprience and the creativity. Then we compared the level of creativity, user-experience and communicability induced by each tool. The results reveal that the user experience arising from the tool influences the amount and the quality of the ideas. Moreover, we show that the fewer standardises interactions the tools have, the greater the communicability of ideas.

1 INTRODUCTION AND RELATED WORKS

Innovation is a succession of activities allowing to bring new concepts coming from a knowledge base that is refined as the project materialises (Le Masson et al., 2006) and being realised by several persons coming from different cultures (Dorta, 2004). The Funnel model (Dunphy et al., 1996) of innovation depicts this refinement of knowledge to emit concepts which can be *in fine* transmitted to design activities. Upstream of innovation, activities will allow widening knowledge of the field to enable new concept proposals; at the end of these activities, generated concepts are more precise. Midler (1995) demonstrated in his model that the supply of knowledge in a project limits the proposal field's freedom to transform it into a concept. These activities of knowledge supply and evolution of ideas and models can be divided and studied independently because they have specific objectives. Lecossier and Pallot (2017) proposed a three-fold segmentation of innovation: (i) "*strategy*" targets the angle of approach to produce new concepts, (ii) "*ideation*" creates new concepts and (iii) "*validation*" selects the most concrete concept to give to the design services. Ideation activities are those that are the most equipped (Gabriel et al., 2016), but there is no consensus on the design, experience, or ergonomics of these tools. Amabile (1983) showed that idea development is influenced by internal markers (e.g., competences, knowledge, motivation, etc.) and external ones (e.g., allowed resources, environment, etc.). It seems important to evaluate the creative experience as it will allow to justify tool choice according to ideation activity requirements. Assessing the user experience will complete the evaluation of the tools and help to understand the needs of the users during creative activities. Several studies have proposed tools to assess the ideation or creative potential of an organisation (Lecossier and Pallot, 2017) or a tool (Cherry and Latulipe, 2014), which can help innovation managers in making their choice. However, these tools do not provide keys to measure the transmission of ideas between stakeholders, which is essential for innovation.

Still today, Computer-Aided Design (CAD) tools, by their place in design activities, are frequently used for the proposition of new models or concepts (Fucci, 2011). Nevertheless, Kosmadoudi et al. (2013) had shown that professional digital tools have low creativ-

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ity performance. These creative problems are due to their complexity and level of abstraction that "lock" users into usage strategies. These tools do not encourage new initiatives, reduce risk taking and finally, user creativity. The transition from ideas to a CAD concept does not allow a perfect maturation of ideas. It seems necessary to simplify tools and/or use game mechanisms to provoke interest and wish to explore tool possibilities. Adding steps, thanks to new tools, might be the solution, if the tools have a benefit compared to traditional tools (Dorta, 2004). To that extent, virtual reality tools seem to agree with these constraints, as several studies had demonstrated the interest of virtual reality for innovation. For instance, Rieuf (2013) demonstrated that his virtual drawing application allowed users to better recognise the emotions the designers had associated with their models. In their study comparing differences of creativity between a pen & paper drawing and virtual drawing, Yang et al. (2018) demonstrated that the virtual application allowed the proposition of more divergent ideas. Feeman et al. (2018) compared CAD and Virtual-Reality CAD (VRCAD) for creativity. Their study highlighted the utility of virtual reality for quick product conception during simple creativity tasks. Finally, Calderon-Hernandez et al. (2019) highlight that immersive representations of a construction are more comprehensible than a 2D drawing. Immersive tools seem to have the potential to enhance conception tasks by adding new features (Fleury et al., 2020). Through this study, we want to demonstrate the potential of immersive tools for creativity.

The present study allowed us to compare the "creative potential" of four tools : pen & paper, CAD, VRCAD, and Virtual-Reality (VR) drawing. We chose to compare these tools according to Dorta's 2004 study claiming that there are not enough steps between an idea design with a simple tool, like a pen and paper, and a CAD software. Thus, our study will allow us to compare virtual-reality tools to traditional ones, based on the quantity and the quality of ideas and user experience. We suppose that the stimulating, clear, and hedonic aspect of a tool will enable a better idea production (Rieuf, 2013; Feeman et al., 2018; Yang et al., 2018). By contrast, we hypothesise that standardisation of interactions will enable users to present more formalised ideas, which will be more understandable and therefore will have better communicability.

To study relationships between user experience, creativity and communicability, we designed a creative task with four different kinds of tools: a pen & paper, VR drawing, VRCAD, and CAD. We measured, through a questionnaire, user experience and communicability. Cropley and Cropley's method was used to assess creativity of ideas. Measured creativity, and communicability were linked to user experience.

2 METHOD

For this study, 79 participants were recruited. They were all trained in the use of CAD software. Participants included 66 (82.5%) men and 14 (17.5%) women. The median age was 22 years old for a standard deviation of 4.33. The youngest of our panel group was 17 years old; and the eldest was 46 years old. Our panel was composed of students coming from engineering training.

2.1 Materials

To compare different tools, possibly used for creativity, we selected four of them. For the two extreme ones, we chose *pen & paper* and *CAD*. The pen & paper is a tool that everyone knows how to use to draw freely and that does not present any constraint of use. For CAD software, we chose *Solidworks* that allows 3D concept modelling through standardised interactions, with a mouse and keyboard, which enable the export of files to other platforms. Moreover our panel used to work with Solidworks.

We selected two intermediate tools in order to validate the benefits and impacts of virtual reality compared to the aforementioned traditional tools. We used the VR application *Time2Sketch* (see figure 1), which works with an HTC Vive and computer with Windows 10. This application allows the user to draw in a 3D virtual environment. The user can find a colour, size and tone palette on the right. By approaching a controller to the palette, the user can select a colour, and by pushing the trigger, the user can draw freely in the environment. One button is placed behind the user to save the drawing and reset the environment. A 3D model of an umbrella is disposed in front of the user. The umbrella can be moved by grabbing it with the controllers.

The last tool is the immersive CAD application *Blocks* (see figure 2). This tool uses some CAD paradigms while maintaining freedom of movement, interaction and visualisation that virtual reality can offer.

2.2 Procedure

As figure 3 shows, the experiment has two parts: (i) the first measures the impact the selected tools have on creativity and (ii) the second assesses the generated ideas communicability for each tool. This study

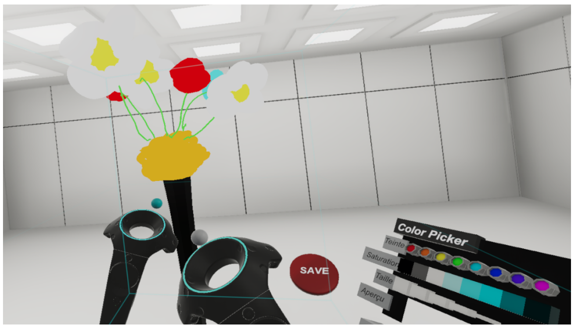

Figure 1: VR drawing application: Time2Sketch.

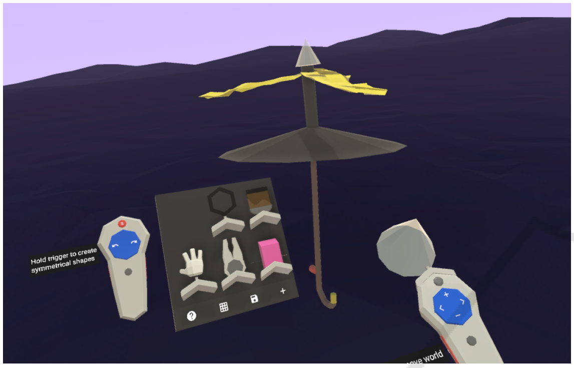

Figure 2: VR CAD application: Google Blocks.

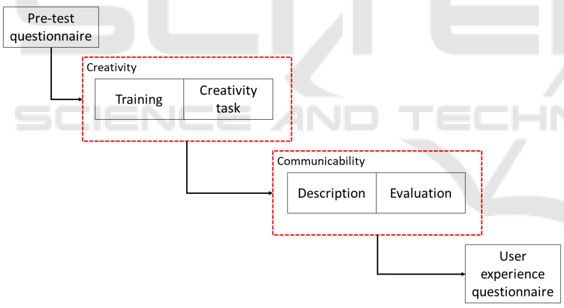

Figure 3: Representation of the experiment proceeding.

follows a between-subject experimental design, with four groups of participants, one per tool. Even if the drawing task was done on their own, the communicability part was done in pairs. Participants had to describe the idea of their partner.

At the beginning of the experiment, participants ware invited to complete the first questionnaire to collect demographic data (gender, age), their ability to use virtual reality and CAD software.

The first phase of experimentation was dedicated to the task of creativity. A training of around five minutes was proposed to participants to help them to get familiar with the tool they will use regarding their group. As aforementioned, participants were selected for their ability to use CAD software. Then participants were invited to carry out a creative task for fifteen minutes which consisted in proposing as many solutions as possible to add new functionalities to an umbrella. Depending on the tool used, participants were given a non-editable 3D model or an A4 sheet paper with a representation of an umbrella from different perspectives. Participants were asked to not take into account any feasibility constraints. Ideas had to be drawn and without text. After the creativity task, participants were invited to complete the *User Experience Questionnaire* (Laugwitz et al., 2008). Following this first phase, each participant was invited to interpret the ideas drawn by the other participant and to write what she/he understood. Finally, the author of the idea evaluated the other participant's interpretation by giving a score from 1 to 9, depending on how well it matched the idea. This mark established our measure of idea communicability.

2.3 Measures

The following measures allowed us to make links between a tool's user experience, creative quality, and ideas communicability :

- Creativity
  - Number of ideas produced.
  - Quality of the ideas (a jury of three persons helped to evaluate the proposed ideas' quality. Their rating was based on four axes : effectiveness, novelty, elegance and genesis, according to the method of Cropley and Cropley (2008) through 23 items).
- User Experience : We used the *User Experience Questionnaire* (UEQ) that measures the attractiveness, perspicuity, efficiency, dependability, stimulation, and novelty of the tool used through 26 items (Laugwitz et al., 2008).
- Communicability : This measure corresponds to a mark, from 1 to 9, assessing how well the other participant's interpretation matches the original idea.

3 RESULTS

Before starting the analysis of our results, we firstly defined the characteristic of our data set. A *Levene*'s test allowed us to verify the heteroscedasticity of all the variables considered, imposing the use of non-parametric tests.

We will first report the results concerning the number of ideas and their creative quality, relatively to each tool. Then we will present the user experience analysis, and we will finish with the study of the communicability of ideas.

3.1 Creativity in Accordance with the Tool

3.1.1 Number of Ideas Produced

A Kruskal-Wallis test revealed a statistically significant difference in the number of ideas per participant according to the tool ($\chi^2 = 44.69; p < 0.01$). Table 1 summarises pairwise comparisons using Mann-Whitney tests and figure 4 shows that the CAD software has a lower median score than the three other tools. The virtual CAD software has a lower median score than a pen and paper.

Table 1: Pairwise comparisons of the amount of ideas per participant for each tool.

	CAD	pen &paper	VR CAD
pen & paper	$< 0.01**$	-	-
VR CAD	0.04*	0.038*	-
VR Drawing	$< 0.01**$	0.908	$< 0.01**$

$*p < 0.05; **p < 0.01$

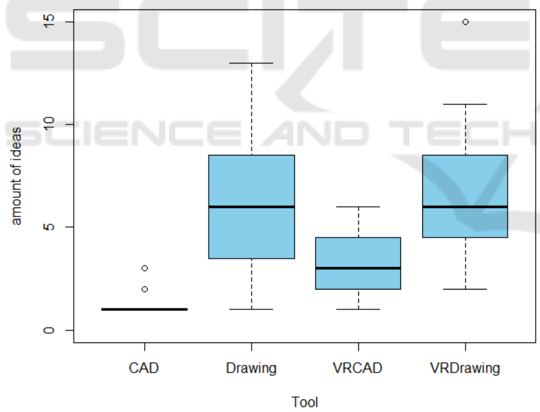

Figure 4: Number of ideas per participant for each tool.

3.1.2 Creative Nature of Ideas

The idea quality analyses are based on the judge's method proposed by Cropley and Cropley (2008). A Cronbach's alpha test revealed acceptable internal consistency ($\alpha = 0.802$) between the rating of the three judges.

First, we analysed the impact of tools on idea quality. A Kruskal-Wallis test ($\chi^2 = 29,62; p < 0.01$) showed a significant statistical difference in the quality of ideas according to the tool. Pairwise comparisons of table 2 showed significant differences between CAD and each other tools, pen & paper and each of the other tools. Figure 5 reveals that a pen & paper have a higher score median than the other tools.

Table 2: Pairwise comparisons of global Cropley's score according to the tool.

	CAD	Pen/paper	VR CAD
Pen & paper	$< 0.01**$	-	-
VR CAD	0.012*	0.041*	-
VR drawing	$< 0.01**$	0.017*	0.99

$*p < 0.05; **p < 0.01$

We then conducted a detailed analysis by considering the scores for the dimensions of effectiveness, novelty, elegance, and genesis. Results of pairwise comparisons are summarised in table 3, and boxplots are presented in figure 5, for each dimension.

Table 3: Pairwise comparison of Cropley's scores according to the tool.

Effectiveness	CAD	Pen/paper	VR CAD
Pen & paper	$< 0.01**$	-	-
VR CAD	0.038*	0.01*	-
VR drawing	$< 0.01**$	0.014*	0.894
Novelty			
Pen & paper	$< 0.01**$	-	-
VR CAD	0.011*	0.237	-
VR drawing	$< 0.01**$	0.07	1
Elegance			
Pen & paper	$< 0.01**$	-	-
VR CAD	0.034*	0.029	-
VR drawing	$< 0.01**$	0.067	0.854
Genesis			
Pen & paper	$< 0.01**$	-	-
VR CAD	0.956	$< 0.01**$	-
VR drawing	0.21	0.126	0.176

$*p < 0.05; **p < 0.01$

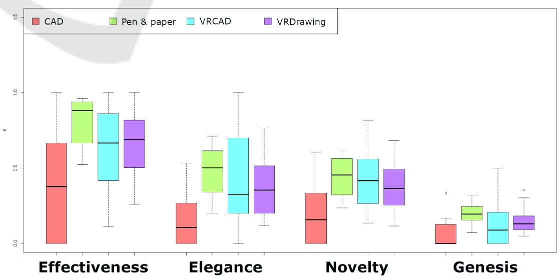

Figure 5: Effectiveness, novelty, elegance, and genesis scores in accordance with the tool.

For the effectiveness dimension, we observed a statistically significant difference between the tools ($\chi^2 = 31.597; p < 0.001$). Table 3 and figure 5 show CAD had a meaningfully lower median of effectiveness than each other tools. Pen & paper had a significantly higher effectiveness median than the VR drawing.

For novelty dimension, we noticed a statistically significant difference between the tools ($\chi^2 = 22.664; p < 0.001$). Table 3 shows significant differences between CAD and each other tools. CAD has a lower novelty median than the other tools (see figure 5).

For elegance dimension, we noticed a statistically significant difference between the tools ($\chi^2 = 22.489; p < 0.001$). Table 3 shows significant differences between CAD and each other tools, pen & paper, and VR CAD. Figure 5 shows CAD has a lower median than the other tools, and VR CAD has a lower median than pen & paper.

For the genesis dimension, we noticed a statistically significant difference between the tools ($\chi^2 = 21.546; p < 0.001$). Table 3 shows a significant difference between CAD, and pen & paper, pen & paper and VR CAD. Figure 5 shows that a pen & paper have a higher median than CAD and VR CAD.

3.2 User Experience Analysis

We relied on the UEQ to measure the user experience induced by each tool. An initial analysis was carried out on the different UEQ dimensions. Table 4 presents Cronbach's alphas for the six UEQ dimensions. To have significant consistency, we removed one item of stimulation and novelty. We had acceptable internal consistency for perspicuity, novelty, and stimulation. However, the internal consistency of efficiency, dependability and attractiveness was too weak to analyse these items.

Table 4: Cronbach's alphas for the differents UEQ categories.

Perspicuity	Novelty	Stimulation
0,76*	0,81 -0.19*	0,79 0.55*

Efficiency	Dependability	Attractiveness
-1,11*	-2,9*	-0,8*

* All items

A Kruskal-Wallis test revealed a statistically significant difference for perspicuity ($\chi^2 = 41.38; p < 0.01$), novelty ($\chi^2 = 30.745; p < 0.01$) and stimulation ($\chi^2 = 32.89; p < 0.01$) according to the type of tool. Then, we carried out pairwise comparisons for these 3 dimensions between each tool.

For the perspicuity dimension, table 5 shows significant differences between CAD tool and VR CAD, VR drawing and CAD, pen & paper, and VR drawing. Figure 6 shows that an immersive tool has a higher median than the other tools for this UEQ dimension.

For the novelty dimension, table 5 shows significant differences between CAD and the drawing tools (VR CAD, and VR drawing). CAD was perceived as less novel than other tools (see figure 6). This novelty evaluation relates to the profile and habits of usage of our participants, who mostly come from industrial conception and engineering domains. Therefore, CAD became the conventional tool, and the other tools were perceived as more novel.

Table 5: Pairwise comparisons for the UEQ dimensions.

Perspicuity	CAD	Pen & paper	VR CAD
Pen & paper	0.06	-	-
VR CAD	$< 0.01**$	0.29	-
VR drawing	$< 0.01**$	$< 0.01**$	0.19
Novelty			
Pen & paper	$< 0.01**$	-	-
VR CAD	$< 0.01**$	0.835	-
VR drawing	$< 0.01**$	0.16	0.616
Stimulation			
Pen & paper	0.405	-	-
VR CAD	0.012*	0.408	-
VR Drawing	$< 0.01**$	$< 0.01**$	0.078

$*p < 0.05; **p < 0.01$

For the stimulation, table 5 shows significant differences between CAD and VR CAD and VR drawing. Also, between pen & paper and VR drawing. Immersive tools seemed to be more inspiring during their usage (see figure 6).

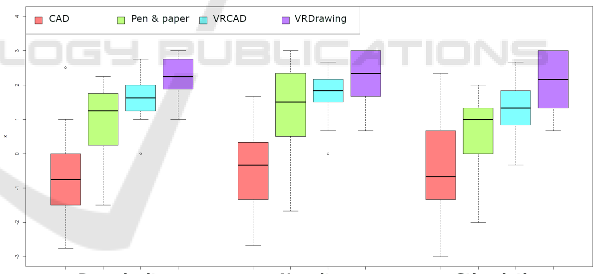

Figure 6: Scores for the perspicuity, novelty and stimulation of UEQ's dimension in accordance with the tool.

These results support correlations between the number of ideas proposed per participant and the UEQ dimensions we considered (see table 6).

Table 6: Correlations between UEQ dimensions and the number of ideas per participant.

	p	Correlation
Perpicuity	$< 0.01**$	0.42
Novelty	$< 0.01**$	0.40
Stimulation	$< 0.01**$	0.40

$*p < 0.05; **p < 0.01$

To conclude this analysis, we tested the correlation between Cropley & Cropley dimensions and the UEQ dimensions. Pearson correlation test revealed existing correlations between UEQ perspicuity and Cropley and Cropley global score and each of its dimensions. Correlations were found between UEQ novelty and Cropley & Cropley elegance and genesis (see table 7).

Table 7: Correlation between UEQ dimensions and Cropley & Cropley scores.

	Perspicuity	Novelty
Total	0.26*	-
Effectiveness	0.23*	-
Novelty	0.28*	-
Elegance	0.27*	0.26*
Genesis	0.28*	0.28*

$*p < 0.05; **p < 0.01$

3.3 Communicability

Regarding the communicability of the ideas generated, a Kruskal-Wallis test ($\chi^2 = 11.335; p = 0.01$) revealed a statistically significant difference between the tools. Table 8 shows substantial differences between pen & paper and CAD and between pen & paper and VR drawing. Figure 7 revealed that a pen & paper have a higher median than the CAD and VR drawing and that a pen & paper and VR CAD have a higher communicability level than the two other tools.

Table 8: Pairwise comparisons of communicability score in accordance with the tool.

	CAD	Pen & paper	VR CAD
Pen & paper	0.025*	-	-
VR CAD	0.807	0.187	-
VR Drawing	1	0.016*	0.794

$*p < 0.05; **p < 0.01$

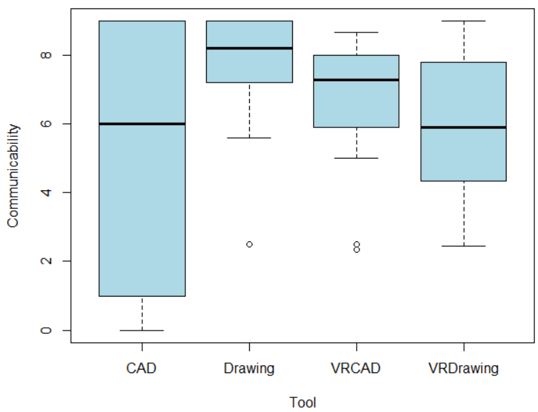

Figure 7: Communicability scores following the tools.

Finally, we analysed if links could exist between user experience measured by the UEQ and communicability. Correlations were not significant (table 9).

Table 9: Correlation between UEQ perspicuity, novelty and stimulation, and communicability.

	Perspicuity	Novelty	Stimulation
Correlation	-0.057	0.18	0.036

$*p < 0.05; **p < 0.01$

4 DISCUSSION

The present study allowed us to compare possibilities of creativity and communicability of four tools (pen & paper, VR Drawing, VR CAD, CAD), each one proposing a particular user experience or use case during creative activities. The task was to sketch new propositions of functionalities of an umbrella. We chose to build a between-subject comparison in order to compare the effect of a tool on creativity and communicability of ideas.

4.1 Tools Influencing Creativity

Firstly, we measured the number of ideas generated by the participants according to the tool used. Pen & paper and VR drawing allowed participants to produce more ideas. This result can be explained by their simplicity of use and the intuitiveness of their different interactions. For both tools, the transition from idea to drawing remains spontaneous and facilitates the production of multiple concepts. Indeed, the VR drawing application enables the user to create 3D sketches, thanks to VR controllers that can be used as brushes, which makes the use simple and intuitive. However, CAD software did not result in the production of a large number of ideas. As an illustration, participants of the CAD group said that a quarter of an hour was too short to provide a single idea from a non-editable model, despite their good knowledge of the tool. In addition, several participants became stuck without being able to produce a single idea. These observations are in line with several studies proving that CAD tools have a complicated interface that facilitates neither artistic creation nor creativity (Kosmadoudi et al., 2013; Feeman et al., 2018; Séquin, 2005). It also confirms Dorta's conclusion (2008) that CAD software should be used when the concept to be designed is sufficiently detailed.

These observations are also supported by the user experience reported for these four tools. A lower level is observed for the perspicuity, stimulation, and novelty dimensions. The low level of novelty observed with the CAD software was related to the usage habits of the participants. This is consistent with the work of Limayem and Hirt (2003), who demonstrated that tool usage habits can favour the development and adoption of strategies and minimise creativity. The lowest CAD scores for perspicuity and stimulation were related to a heavy interface and standardised interactions, which do not simplify clarity and do not encourage users to be more creative.

We observed correlations between the number of ideas and UEQ perspicuity, stimulation, and novelty. Thus, as a better user experience was measured for the least standardised tools, we assumed that the ease of use allowed participants to generate more ideas and go into further detail. We conclude that to encourage creativity, it is better to have unusual tools and a light and stimulating interface. These results are in line with the findings of Gonçalves et al. (2015).

In addition to the number of ideas produced, we evaluated their quality, using the method of Cropley and Cropley (2008). We observed that a pen & paper allowed the participants to create more qualitative ideas, contrary to the CAD software, which obtained only low scores.

The correlation between the overall creativity score and the UEQ perspicacity suggests that an easy-to-use tool is conducive to the generation of uncommon and divergent ideas. The interactions provided by the VR tools remain simple and favoured and high-quality ideas. We noted that the most creative ideas were usually set in a context or a more detailed environment. This observation was linked to a correlation between UEQ perspicuity and the different dimensions of the Cropley & Cropley rating method. Indeed, ease of use encouraged users to detail their ideas by providing a context of use or an environment that made them easier to understand. For example, figure 8 shows an idea drawn with the VR CAD tool; it represents an umbrella which can be used to fly.

We also observed that the originality of the tool favoured the elaboration and transposition of ideas to other issues. The avant-garde and unexpected aspect stimulated the users' creativity and immersed them in their task. Finally, it is interesting to note that a pen & paper, by its simplicity, allowed users to be more creative.

4.2 Idea's Communicability

Beyond the quantity and quality of the ideas produced, we were interested in their communicability. Through a brief description by another participant and a rating of the fidelity of this description by the author of the idea, we measured the communicability of each idea in relation to the tool used. The results revealed that a pen & paper allowed better communicability of ideas. Also, VR tools had a higher level of communicability than the CAD tool. No link was found between UEQ dimensions and communicability. However, we believe that the context and details added to the ideas promoted communicability. Further studies would be required to investigate this hypothesis.

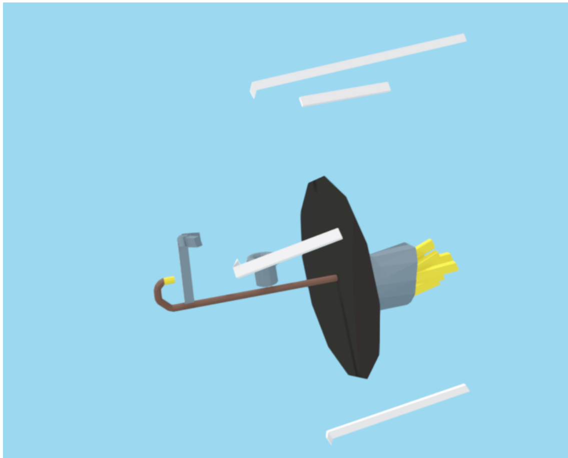

Figure 8: Immersive CAD idea judged with a high creativity score. It represents an umbrella with a jet engine attached on it to allow it to fly.

The superiority of a pen & paper can also be explained by the fact that the participants were working on an A4 sheet whereas the VR software presented a real-size model that required larger gestures and more energy to draw an idea. To favour idea communicability, tools must support users to design surroundings and to design details. For VR tools, a simple interaction to resize the object can help to minimise the effort to contextualise the idea drawn.

5 CONCLUSION

This study revealed the existing links between user-experience, creativity and communicability thanks to four tools. It revealed that the number of ideas was linked to perspicuity, novelty and stimulation driven by the different tools. On the other hand, communicability of an idea is determined by the ability of a tool to give some background. In view of the results, we can consider new fields of investigation for further studies.

We demonstrated, in the context of a drawing task, that the ease of use and the stimulating nature of a tool had a positive effect on the user's creativity. The ease of use allows more time for thinking, allowing users to propose more divergent ideas. In this respect, a link can be observed with the cognitive load described by Sweller (1988) as we assume that tools with a complex interface and interactions will increase the cognitive load required to establish mental patterns for translating the idea from a thought to a concept. It seems important to reduce the cognitive load of users to enable them to generate more ideas or to be able to inhibit environmental stimuli that can interrupt the flow of thinking. If the tools we proposed were devoid of environment or run in a minimalist environment, it would not be the same as in a work context where there are elements which are more or less relevant. One perspective of this work would be to measure the impact of the environmental stimuli on cognitive load in relation to the work of Amabile and Pratt (2016).

The second perspective of our work concerns the communicability of ideas. We relied only on representations to measure communicability. In a professional context, ideas can be communicated by viewing, reading, explaining, etc. In order to offer an interface model dedicated to the communication of ideas, it seems essential to conduct a study on the different visualisations paradigms of 3D concepts generated in an immersive environment.

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