CRUX : A CReativity and User eXperience Model

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Abstract

The field of Virtual Reality has been developing at a steady pace, and VR is finding new uses as a support for creative tasks. The objective of this study is to propose a theoretical model describing the links between user experience and creativity. Pre-existing theoretical links have been identified in relevant scientific literature. Two experiments were then conducted in order to identify new links and replicate results. These experiments involved respectively 76 and 42 participants who individually performed a task requiring divergent creativity using virtual reality drawing tools. The results indicate that cybersickness leads to a decrease in fluency, i.e. the number of ideas generated, but also shades the links between flow and the relevance of the ideas generated. On the basis of this result, we propose the CRUX model to lead to recommendations for the design of tools and simulations to support divergent creativity.

Keywords : Creativity, User Experience, Digital tools, Cybersickness, Virtual reality

1. Introduction

The development of digital tools has led to significant changes in idea generation practices during the upstream phases of product design. In particular, the development of Virtual Reality (VR) opens up new possibilities in this field.

Recent research has attempted to quantify the benefits of VR ideation tools. Yang et al. (2018) compared performance in a creative task between a 'pen/paper' and a 'VR' condition in which the participants had to draw in immersive three dimensions. In this study, the use of VR allows the authors to treat the creativity task as a 1:1 drawing activity. This leads to better creative performance when compared to drawing on paper (that is a two dimensional plan) because the participants do not have to perform any mental transformations to match their

gestures and the object being drawn. Feeman, Wright and Salmon (2018) compared the use of a computer-assisted design software with that of an equivalent VR-based tool. Here again, the simplification of interactions resulting from the users' natural gestures tends to facilitate creative tasks.

The ability of digital tools to support creativity has been the subject of various recommendations. Buxton (2007) states that a relevant creativity tool should allow for "cheap" sketches that are quick and simple, so that the user is unencumbered by the fear of realising an idea that does not seem relevant to him. Similarly, we find the Creativity Support Index (Cherry & Latulipe, 2014) which allows, through the participants' answers, to identify the improvements to be made on a tool in order to make it more conducive to creative tasks. Buxton's (2007) recommendations and the Creativity Support Index are useful when designing or improving digital tools for creativity. However, the limitation of these two works is that they treat creativity as a one-dimensional process. Some recommendations could lead to an improvement in the number of ideas generated while another one could lead to ideas with a better feasibility. In both cases, it is a question of improving creativity, but on different criteria.

Creative thinking is composed by two main processes depending on the type of task : divergent thinking is when the participants have to generate numerous creative ideas, while convergent thinking consist in following a set of logical steps to arrive at a correct solution. The abovementioned experiments in VR are based on divergent thinking tasks (Feeman *et al.,* 2018 ; Yang *et al.,* 2018) and this is the type of task we are interested in. To qualify a set of ideas generated in a divergent creativity session, Guilford's (1960) criteria appear relevant. These are: Originality (which evaluates whether the participant's ideas were unique when compared to other participants), Fluency (the number of ideas generated), Flexibility (the number of ideas belonging to different domains or categories) and Elaboration (the amount of added detail given for each idea). Another approach, called "Consensual Assessment Technique" consists of asking expert judges in the field to evaluate the level of creativity of ideas by means of a score (Amabile, 1982). This approach does not seek to qualify the different facets of ideas, but rather to rank their relevance on the basis of expert opinions.

The user experience during the use of immersive technology has been investigated in many studies. It is defined in the norm ISO 9241-210 as the « user's perceptions and responses resulting from the use of a system or a service ». Concerning specifically the use of VR, Tcha-Tokey et al. (2018) included flow, emotion and « simulator sickness », also named « cybersickness » as components of user experience. Cybersickness is a discomfort following a prolonged use of VR device (Porcino et al., 2017).

We can see that the different forms of creativity, or the different qualities that an idea or group of ideas may have are varied, but the different criteria used to quantify the same do not necessarily co-vary. Our objective in this paper is to propose a first version of a model that we call CRUX (contraction of Creativity and User eXperience) that aims at giving a general representation of the links between the dimensions of the user experience associated with the use of digital creativity tools and the different facets of creativity. In terms of recommendations, our work is about being able to propose improvements to a tool in a specific way according to the precise performance objectives of a given work session.

At this stage, we have identified 6 such links clearly established in literature:

- MacDonald, Byrne & Carton (2006) discovered a positive link between flow and overall creativity as assessed by a consensual technical assessment, and this link was confirmed in an independent experiment by Yang *et al*. (2018).
- Fleury *et al.* (2020) demonstrated an effect of visual movement on the fluency of divergent ideas.
- Performing an unusual activity tends to increase cognitive flexibility and thus the variety of ideas proposed (*e.g.* Ritter et al., 2012).
- Positive affective factors are associated with the flexibility in generation of new ideas (*e.g.* de Rooij, Corr and Jones, 2017; de Rooij, Corr and Jones, 2015; Marinussen and de Rooij, 2019).
- Positive affective factors are also associated with generating original ideas (*e.g.* de Rooij et al., 2017; de Rooij et al. 2015).
- Stress has been identified as a factor that reduces creative flexibility (*e.g.* Baer & Oldham, 2006).

In this paper, we describe the method and results of an empirical study that investigates the links between user experience and creativity in virtual environments. The objective of this study is to identify new links, and integrate them into existing theoretical models.

2. Experiment 1

Several recent studies have highlighted the importance of cybersickness in VR user experience (e.g. Servotte et al., 2020). This variable has not been studied in relation to creativity as it is specific to immersive devices. However, cybersickness is known to have more general effects on both physiological and cognitive dimensions of individual usage (Nalivaiko et al., 2015). Thus, it seems that in VR, cybersickness represents a very important part of the user experience and ignoring its consequences on creativity is detrimental to imagine and design VR tools for creative activities.

This leads us to hypothesise that in a task of divergent creativity in VR, the level of cybersickness experienced by participants should be negatively correlated with all dimensions of measured performance: elaboration, fluency, flexibility and originality (see Figure 1).
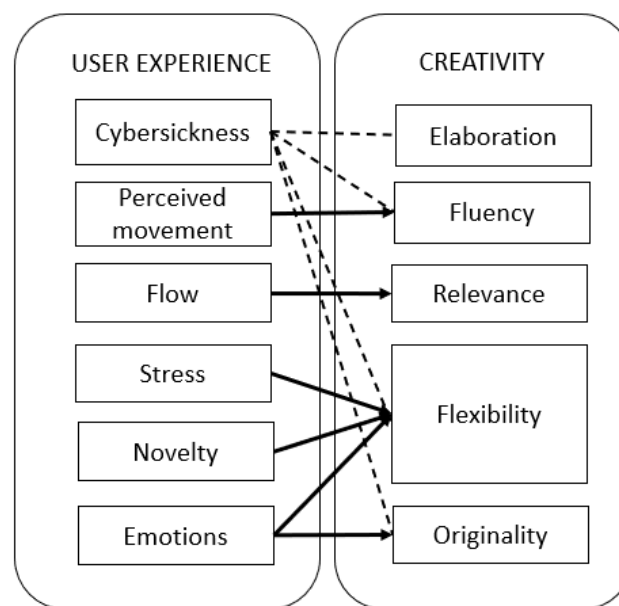

Figure 1. Representation of the links identified in the literature (solid lines) and the hypotheses of the present experiment (dashed lines).

2.1. Method

We conducted a study involving 76 participants of various profiles (students, working adults), 39 males and 37 females. They ranged in age from 12 to 64 years with an average age of 24.4 years (SD=15.6). The participants were individually asked to perform a VR creative task. They were immersed in a virtual environment with a HTC Vive Head-Mounted Display in the presence of a 3D model of a backpack (See Figure 2.). Within a time limit of 15 minutes per session, participants had to imagine and draw as many solutions as possible to the following prompt: "The backpack is heavy on the backs of school children, find solutions to solve this problem". They were then allowed to draw freehand around the backpack in VR to suggest improvements. They were asked to be free and come up with bold ideas to solve the problem. This task was performed using an immersive drawing tool. The instructions were given orally to the participants.

This test leads to the collection of a set of ideas for each participant. Each set of ideas was then analyzed and characterized on the basis of the four criteria proposed by Guilford (1960) which constitute the scores of originality, fluency, flexibility, and elaboration. After completing the creativity task, participants were asked to

complete the Simulation Sickness Questionnaire (SSQ; Lane and Kennedy, 1988), so that we could assess correlations between the two datasets.

Figure 2. Screenshot of the VR drawing software (left) and example of an idea (right)

2.2. Results

The normality of the creativity variables was tested with Shapiro-Wilk tests. These indicate that none of the four variables have Gaussian distributions - flexibility (W=.91, p<.001), fluency (W=.96, p=.011), elaboration (W=.82, p<.001) and originality (W=.69, p<.001).

As recommended, the cybersickness score is an addition of the 0 or 1 responses of the participants on the 16 items of the SSQ. The links between creativity and cybersickness has been tested by Spearman correlations which are described in Table 1, because the creativity criteria do not follow a normal distribution. This analysis reveals a significant negative link between Cybersickness and Fluency, which indicate that an increase of Cybersickness would be associated with a decrease of Fluency. Nevertheless, Cybersickness does not appears to be corelated with Flexibility, Elaboration and Originality.

Table 1. Correlation matrix linking cybersickness and creativity criteria

	Fluency	Flexibility	Elaboration	Originality
Cybersickness	**R=-.24**	R=-.22	R=-.20	R=-.02
	P=.041*	P=.055	P=.090	P=.890

*p<.05

2.3. Discussion

A number of links have previously been identified between dimensions of user experience and creativity criteria (Figure 1). The first experiment in our study consisted of asking participants to perform a divergent creativity task in VR in order to establish the links between cybersickness and the various creativity criteria proposed by Guilford: elaboration, fluency, flexibility and originality.

The results indicate that cybersickness has a significant effect on the Fluency criterion, *i.e.* the number of ideas generated during the limited time of the experiment. The discomfort felt by users in VR varies according to the characteristics of the hardware (Freiwald, Katzakis & Steinicke, 2018), the software (Jung, Cho, Choi & Choi, 2017; Porcino, Trevisan & Clua, 2019), the type of task (Park, Choi, Kim & Kim, 2005), but also the individual (Risi & Palmisano, 2019). It is therefore important in the design of ideation tools to follow good practices to design technologies that will minimize cybersickness (Porcino et al., 2017; Choroś & Nippe, 2019) and thus maximize the number of ideas generated by users.

3. Experiment 2

The above-mentioned link between flow and relevance has been highlighted in two independent studies (MacDonald et al., 2006; Yang et al., 2018). This link thus seems quite consistent, but in both cases, the authors only measured the general relevance of the responses without evaluating other creativity criteria. The possible links between flow and other creativity criteria have therefore not yet been assessed. This is the purpose of the second experiment in our study.

Yang *et al*. (2018) conducted an experiment to compare task performance of drawing creative sketches on paper and in VR. Their study demonstrated that the VR condition better supported the state of flow, which in turn had a favourable impact on the relevance of ideas.

In our experiment, we repeat this type of comparison (VR vs. pen & paper), while also evaluating other types of creativity criteria based on the work of Cropley and Cropley (2008) in order to more precisely identify the relative differences in terms of creativity between the two conditions.

The hypothesis of this experiment is that the VR environment will lead to an increased relevance of the ideas generated, corresponding to the "effectiveness" criterion of Cropley and Cropley (2018), in line with the results of Yang et al. (2018) and MacDonald et al. (2006). It is therefore a question of confirming a link already identified in literature, but with additional measures of creativity as well.

Flow is a very important dimension that impacts executive functions (Golub, Rijavec & Olčar, 2016). To the best of our knowledge, no study links flow with criteria other than relevance, however it may be reasonable to think that flow could have consequences on the other creativity criteria described by Cropley and Cropley (2018), such as elegance, novelty, and genesis, and also the number of ideas generated. We hoped to determine the same through our study.

3.1.   Method

For this second study, 42 participants were recruited. They include 37 men and 5 women. The median age is 21 years, with a standard deviation of 2.39 years. The youngest participant was 17 years old and the eldest was 26 years old.

Each participant had to carry out a creativity exercise either with pen and paper (Pen&Paper condition), or with the same VR drawing software as described in the previous experiment (VRDrawing condition). A training period of around five minutes was provided to the participants in order to help them get familiar with the tool they will be using, depending on which condition they were placed in. The participants were then asked to propose as many solutions as they can in the time available to add new functionalities to the umbrella. The participants were given 15 minutes to complete this creativity task. Depending on the tool used, participants were given a non-editable 3D model in VR, or an A4 paper with a representation of an umbrella from different perspectives. No constraint on the feasibility of the ideas proposed was placed on the participants.

To evaluate the quality of the proposed ideas, a jury of three persons was formed. The rating of the different ideas is made on four axes: effectiveness, novelty, elegance and genesis, in accordance with the method of Cropley and Cropley (2008), through 23 items.

3.2.   Results

We performed a consistency test on the idea quality analyses made by the jury members, based on the method proposed by Cropley and Cropley (2008). A Cronbach's alpha test reveals acceptable internal consistency (a = .802) between the ratings of the three judges.

The normality of the creativity variables was tested with Shapiro-Wilk tests. These indicate that novelty (W=.97, p=.503), genesis (W=.96, p=.123) and elegance (W=.96, p=.152) have Gaussian distribution, unlike the number of responses (w=.94, p=.026) and effectiveness (w=.94, p=.037). Thus, the first three were tested using a

parametric t test and the two latter were tested using a non parametric Kruskal-Wallis test. All these inferential comparisons are reported in the table 2. They reveal a significant superiority of Pen&Paper condition for Effectiveness compared to VR condition, and no statistically significant difference between the conditions for Elegance, Novelty, Genesis and Fluency.

Table 2. Creativity scores in *Pen&Paper* and *VRdrawing* conditions, Mean (Standard Deviations)

	Pen&Paper	*VRDrawing*	Comparison
Effectiveness	**0.81(0.15)**	**0.66(0.20)**	**Chi2(1)=4.81, P=.028***
Elegance	0.47(0.16)	0.37(0.18)	P=.057
Novelty	0.44(0.13)	0.38(0.16)	P=.200
Genesis	0.19(0.07)	0.15(0.08)	P=.075
Fluency	6.10(3.11)	9.85(3.57)	Chi2(1)=.15, P=.703

*p<.05

3.3.   Discussion

The objective of this second experiment was to test the previously identified link between the flow and relevance of ideas, with different measures of creativity criteria based on Cropley and Cropley (2018). The experiment is based on the comparison between an ideation situation using paper and pencil, and a VR drawing situation - a comparison that has previously yielded a strong difference in terms of flow (Yang *et al.,* 2018).

The results of our study are quite surprising because they indicate a statistically significant superiority of relevance (corresponding to effectiveness in the Cropley and Cropley criteria), in Pen&Paper condition compared to VR condition. Comparisons with the other creativity criteria do not reveal significant relationships.

We therefore get really different results from those of MacDonald *et al*. (2016) and Yang *et al.* (2018). Concerning MacDonald *et al.* (2016), the creative task consisted in music composition, which is very different from our task of immersive sketching. However, if we compare our experiment to that of Yang *et al.* (2018), the softwares were quite identicals, as well as the task. We may hypothetize that the difference between the two studies comes from the participants sample. In the study of Yang *et al.* (2018), the participants were not particularly familiar with VR, while our participants were students specialized in VR. Thus, for our participants more accustomed to VR than to drawing on paper, the paper drawing exercise may have been more stimulating (because it was more unusual) than the VR exercise. In any case, we can see that the question of the link between flow and relevance of creative ideas is not really solved. Further studies will be necessary to clarify this link.

4. Conclusion

The objective of this study was to propose a comprehensive model linking user experience and creativity based on existing, individual links identified in literature, and to enrich it with data on the relationship between cybersickness, flow and creativity. This first version of the model which we name *CRUX* (for CReativity User eXperience) is depicted in Figure 3.
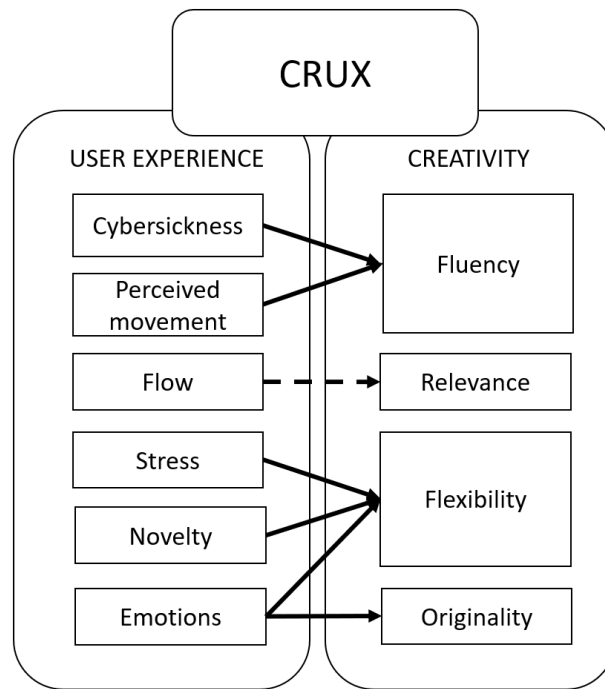
CRUX

USER EXPERIENCE

Cybersickness

Perceived movement

Flow

Stress

Novelty

Emotions

CREATIVITY

Fluency

Relevance

Flexibility

Originality

Figure 3. A first version of the CRUX model

This model makes it possible to make specific recommendations for the design or use of creativity tools according to specific objectives and situations. For example, the introduction of visual movement in an application is adequate to increase the number of ideas generated, while encouraging positive emotions (for example through play) is appropriate when seeking to obtain a wide variety of original ideas. However, this model in its current form is still a proposal for improvement. Further studies are needed to strengthen the reliability of the links presented here, particularly the link between flow and relevance, but also to verify the place that other variables that are missing here could have, such as hedonic qualities from the side of user experience, or elaboration of ideas on the side of creativity assessment. We believe this study is a good first step towards that goal.

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