Avatar-mediated creativity: When embodying inventors makes engineers more creative

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An important challenge today is to support creativity while enabling geographically distant people to work together. In line with the componential theory of creativity, self-perception theory and recent research on the Proteus Effect, we investigate how avatars, which are virtual representations of the self, may be a medium for stimulating creativity. For this purpose, we conducted two studies with a population of engineering students. In the first study, 114 participants responded to online surveys in order to identify what a creative avatar may look like. This enabled us to select avatars representing inventors, which were perceived as creative by engineering students, and neutral avatars. In the second study, 54 participants brainstormed in groups of 3, in 3 different conditions: in a control face-to-face situation, in a virtual environment while embodying neutral avatars and in a virtual environment with inventor avatars. The results show that inventor avatars led to higher performance in fluency and originality of ideas. Moreover, this benefit proved to endure over time since participants allocated to inventor avatars also performed better in a subsequent face-to-face brainstorming. The prospects of using avatars for enhancing creativity-relevant processes are discussed in terms of theoretical and applicative implications.

1. Introduction

Creativity is the starting point to change the product range and offer new services in a context in which companies have to innovate and differentiate from their competitors. Therefore, finding relevant new methods to stimulate creativity and foster innovation becomes a key issue. Moreover, technological and organizational developments (collaborative design, distributed teams, etc.) create new challenges: creative methods must be consistent with this new reality of work. In this respect, virtual environments may help connect geographically distant people, but also support, or even improve, creativity and innovation.

Much work has focused on the design of computational systems to support creativity (e.g. Afonso Jaco, Buisine, Barré, Aoussat, & Vernier, 2014; Lee, 2015). Classical platforms used for this purpose include, for example, electronic brainstorming systems, which have been the subject of research in Human-Computer Interaction and Psychology (e.g., DeRosa, Smith, & Hantula, 2007; Michinov & Primois, 2005; Michinov, 2012). However, in line with a *cybercreativity* analysis of virtual worlds (Nelson, Guegan, & Lubart, submitted), it seems possible to go a step further. In particular, the present paper focuses on the avatar (i.e., digital representation of the self) as a potential vector for stimulating creativity. The avatar is a character, often customizable, which represents user's identity in the virtual environment (Meadows, 2008). Avatars are interface items that are considered particularly attractive, hedonic and persuasive (Nemery & Brangier, 2014). They are a central component of many gamification systems (Hunicke, Leblanc, & Zubek, 2004;

Singer & Schneider, 2012). Gamification, which refers to the use of game design elements in non-game contexts (Deterding, Khaled, Nacke, & Dixon, 2011), is generally used to increase user experience and engagement (Dominguez et al., 2013). For all these reasons the use of avatars in creativity sessions seems promising and timely.

Avatars are projections of users, a “tangible embodiment of their identity” (Ducheneaut, Wen, Yee, & Wadley, 2009). Users can create avatars looking like them, experience a multiplicity of identities or highlight certain aspects of their ideal self (Bessière, Seay, & Kiesler, 2007). Thereby, the configuration of avatars allows users to change their appearance, their social roles and their identity in the virtual world. The relationship between users and their avatars may even provide support to engage people with lifelong disability in activities and social interactions (Stendal, Molka-Danielsen, Munkvold, & Balandin, 2012). Furthermore, a growing body of research supports the idea that avatars' appearance influence users' behaviors in the virtual world (Yee & Bailenson, 2007). This kind of phenomenon leads us to investigate the potential impact of avatars on creativity-relevant processes, and the effects of embodying a creative avatar on users' creative performance. To substantiate this endeavor, Section 2 reviews the theoretical background and literature on avatar-modulated behaviors and Section 3 provides the theoretical articulation with the creativity framework.

2. The influence of avatars on behaviors and attitudes

The influence that the avatars may exert on users has been the subject of several experimental studies over the past decade. On a theoretical level, these studies are based on research on the effects of anonymity and identity cues.

In line with the seminal proposals of *self-perception theory* (Bem, 1972), the individual explains his attitudes and internal states based on observation of external cues. Therefore, the individual would adopt the same point of view as an external observer “who must necessarily rely upon those same external cues to infer the individual's inner states” (Bem, 1972, p.3). For example, Frank and Gilovich (1988) showed that participants wearing black uniforms exhibit more aggressive behavior than participants wearing white uniforms. This phenomenon was observed both in laboratory and in natural environment. Moreover, this self-perception process can be linked to *deindividuation* (Diener, 1980; Festinger, Pepitone, & Newcomb, 1952), which refers to a behavioral modulation in situations of anonymity. Indeed, although deindividuation was initially seen as a negative phenomenon (i.e., which leads to aggressive and antisocial behaviors; see Postmes & Spears, 1998 for an overview), subsequent research has shown that deindividuation is quite neutral but may increase the sensitivity of individuals to environmental influences (e.g., Gergen, Gergen, & Barton, 1973; Spivey & Prentice-Dunn, 1990). For instance, it has been shown that participants exhibit more prosocial behavior when wearing a nurse costume rather than a Ku Klux Klan uniform (Johnson & Downing, 1979), which is consistent with expectations an external observer might have. However, this study also showed that the participants in nurse costume behaved in a more prosocial way when they were anonymous (i.e., deindividuated). Consequently, it can be considered that deindividuation does not necessarily lead to aggressive and antisocial behavior, but also (and perhaps most importantly) that “deindividuation increases the self-perception reliance on identity cues” (Yee, Bailenson, & Ducheneaut, 2009, p.292).

This reasoning can be transposed to avatars in virtual environments. As noted by Yee and Bailenson (2007), virtual environments are conducive to deindividuation because of the physical isolation and the anonymity of the users. Moreover, the avatar may greatly influence self-perception process as it is even more than a costume or a uniform that is worn: “the avatar is our entire self-representation” (Yee & Bailenson, 2007, p.274).

In situation of anonymity in virtual environment, the digital representation of the self may thus influence users and rationalize their behaviors to be consistent to the avatar's identity. This behavioral modulation related to the appearance of the avatar, known as *Proteus Effect* (from the Greek God Proteus who possessed the ability of metamorphosis), has been observed in several studies. Yee and Bailenson (2007) have shown that attractive avatars lead to behave in a more intimate way in terms of self-disclosure and interpersonal distance (see also Waddell & Ivory, 2015). It should be noted that this phenomenon results from the mere exposure to a virtual mirror allowing the participant to see his/her avatar for about 1 min. In this respect, it can be considered that the Proteus Effect is initiated almost instantly. In another study, Yee and Bailenson (2007; Yee et al., 2009) have shown that tall avatars lead to more confident behavior than short avatars in a negotiation task. Recent studies have also shown that the appearance of the avatar may affect subsequent behavior in the real world (Rosenberg, Baughman, & Bailenson, 2013; Yoon & Vargas, 2014). For example, the benefits of a tall avatar on negotiation endures in a subsequent negotiation task in face-to-face situation (Yee et al., 2009). Likewise, it was found that the weight of avatars influence real life physical activity during motion gaming sessions (Peña, Khan, & Alexopoulos, 2016; Peña & Kim, 2014).

Beyond behavior, it has also been shown that avatars could influence attitudes and productions of the users. For instance, the embodiment of female avatars, with an appearance more or less sexualized, can impact perceptions and judgments towards women (Fox, Bailenson, & Tricase, 2013), and the use of a doctor vs. a Ku Klux Klan avatar can influence the content of stories composed by the users (Peña, Hancock, & Merola, 2009). Since the latter study shows that avatars' appearance modify narrative productions, which somehow are related to a creative or imaginative process, we think that the influence of avatars on creative processes is worth investigating. In the following section, we elaborate on how this effect could occur and which component of creativity it may impact.

3. The use of avatars for creativity

Creativity can be defined as the capacity to produce novel, original work that fits with task constraints (Sternberg & Lubart, 1999). It is said to be a cornerstone of innovation and of the knowledge economy (Florida, 2002). The *Componential Theory of Creativity* (Amabile, 1983, 2013) posits that four components are essential to creativity: three intra-individual components—Domain-Relevant Skills, Creativity-Relevant Processes and Intrinsic Task Motivation—and an external component corresponding to the Social Environment. A considerable amount of research has been devoted to capturing the influence of the social environment and of the motivational component on creativity (Amabile, 2013). It has notably been shown that the imposition of salient extrinsic constraints undermines intrinsic motivation and subsequently decreases creative performance (Amabile, 1985). This effect can be explained by the self-perception theory (Bem, 1972), which predicts that the presence of extrinsic motivators such as rewards triggers an overjustification mechanism resulting in a decrease in intrinsic motivation and a decrease in creativity.

The two other intra-individual components of creativity have been the subject of fewer experimental manipulations. Domain-Relevant Skills correspond to knowledge about and experience in the task domain, technical skills or talents. They mainly depend on innate cognitive/perceptual/motor skills as well as on formal and informal education (Amabile, 1983). Finally, Creativity-Relevant Processes correspond to personality traits, cognitive styles, working styles and heuristics for generating creative ideas. Some of them can be enhanced through training, others are related to personality characteristics such as independence, risk-taking or tolerance to ambiguity (Lubart, Mouchiroud, Tordjman, & Zenasni, 2003).

Contrary to the motivational component of creativity, there was, to the best of our knowledge, no attempt to leverage Creativity-Relevant Processes on the basis of the self-perception theory. However, considering the reported studies on the Proteus Effect, we believe that it should be possible to improve the perception of one's creative skills and to improve one's creative performance through the use of avatars. In the same way as Ku Klux Klan avatars lead users to imagine more negative stories (Peña et al., 2009), a “creative” avatar could arouse more creative behaviors which would lead to more innovative ideas. Our research question then becomes the following: May creativity be enhanced through a self-perception mechanism triggered by the use of relevant avatars? Since Creativity-Relevant Processes are related to individual characteristics, providing someone with a self-representation featuring such characteristics should lead to more creative behaviors. Indeed, through self-perception process, one might consider that he possesses these characteristics (as an external observer would) and therefore implement the related creative processes. Such self-perception mechanism may help individuals express their creative potential and constitute an original approach to increase creative performance.

To investigate the influence of the Proteus Effect on creativity, we designed a digital tool using avatars to conduct creativity sessions. We chose engineering students as a first population because creativity, which leads to invention and innovation, is part of nowadays engineers' essential skills. That said, this situation raises an important question: What is the right digital self-representation for creativity? And in particular, what is the right representation to support engineers' creativity? Because the appearance of avatars is central to the Proteus Effect and self-perception process, the first step consists in finding relevant digital representations of “creative people”. However, since physical features and personality traits that characterize creative people are multidimensional and non-exclusive (e.g., Lubart et al., 2003), the prototypic avatar for creativity may reasonably not exist, but may emerge from representations of what “being creative” means. Therefore, our first aim is to identify the cognitive representation of engineers when they think of what a creative character looks like. Then, a second step will be to experimentally test the influence of such avatars in the virtual environment and in subsequent face-to-face creativity task.

In consequence, the present research is based on two studies:

1) Identification and design of the right digital self-representation for creative engineers. The aim is to objectify a broad concept such as Creativity-Relevant Skills for engineers and provide virtual representations for this concept.
2) Test of the avatars designed during the first study and measurement of their influence on the creative performance of groups of engineers.

4. Study 1: design and evaluation of the avatars

For this research we chose to use the virtual world Second Life from Linden Lab, because it is readily accessible and one of the most widely used “sandbox” virtual world. It also has straightforward programmable scripting and programming possibilities that will make the experimental conditions possible, and is cost effective due to the large amount of content already available (clothing, buildings, indoor and outdoor settings, etc.).

The study consisted in designing a collection of avatars using Second Life facilities and making them evaluated by engineering students. For this purpose, we used two online collaborative tools: a questionnaire-like tool and a facemash-like application.

4.1. Participants

A total of 114 students from a multi-site higher engineering institute in France participated in this study through the online collaborative tools: 45 students filled in the questionnaire and 69 participated to the facemash. The links to the surveys were circulated through internal mailing lists restricted to students, which enabled us to target several subgroups in the general population of students, for example in different sites in France. This procedure ensured that we had different respondents to the two evaluation systems.

4.2. Material

Based on preliminary interviews with engineering students and teachers, we hypothesized that the image of the inventor (as opposed to the image of the artist for example) should carry the strongest creativity-relevant processes from the point of view of engineers, and therefore be the most relevant representation of creative skills for this population. We subsequently created two corpora of avatars: one series of 18 “inventor” avatars and one of 12 “non-inventor” avatars, including 4 colorful avatars with an exuberant look, closer to the representation of the artist, as distractors to the concept of the inventor.

To assess the relevance of these avatars, we developed a questionnaire composed of five items: (1) *This character is attractive*; (2) *This character seems to be able to cooperate with others during a brainstorming session*; (3) *This character could give innovative ideas*; (4) *This character seems sociable and extroverted*; (5) *This character looks like an inventor*. Questions #2, #3 and #5 were directly related to the study purpose, while question #1 and #4 were included as control variables (e.g., check whether the inventors we designed were more or less attractive than the non-inventors avatars). Each item was associated to a 7-point scale (1 = *Not at all*; 7 = *Absolutely*).

The Facemash system (see also Guegan, Maranzana, et al., 2015), inspired by the precursor of Facebook, is a direct pairwise comparison method. The evaluator has to compare two avatars in each run and chooses the one that best matches a given feature (here: look like an inventor, see Fig. 1). Once the “winning” avatar is selected, a new run is displayed with 2 new avatars to compare. In the two evaluation systems, the avatars were presented through 2 pictures (headshot and full-length portrait) and their order of appearance was randomized.

Fig. 1. Facemash direct pairwise comparison tool.

4.3. Procedure

The evaluation systems were distributed online and each participant had the possibility to respond to as many questions or comparisons as wanted and stop when desired.

4.4. Results

4.4.1. Questionnaire

The perception of the "inventor" appearance proved to be positively correlated to the ability to produce innovative ideas ($r = 0.79$; $p < 0.001$). In addition, the perception of the avatar as likely to produce innovative ideas was positively correlated to its ability to cooperate with other group members ($r = 0.46$; $p < 0.01$). These three items, directly related to the perception of creative skills (i.e., inventor, innovative ideas and cooperation), are organized along the same creativity-relevant dimension (Cronbach's alpha = 0.73).

Moreover, the perception of attractiveness and extroversion of avatars were positively correlated ($r = 0.58$; $p < 0.01$) and did not correlate to other items. This second dimension, independent from the first one, corresponds to the social and relational aspect of avatars (i.e., attractive, sociable, extroverted).

The 30 avatars were ranked according to their score to item #5 (i.e., *This character looks like an inventor*), which enabled us to extract from the corpus two sets of 4 avatars: the 4 avatars (3 male and 1 female) with the highest scores for the inventor set, and the 4 avatars (3 male and 1 female) with the lowest scores for the non-inventor set (see Fig. 2). We selected 4 avatars, including a female one, for each set because study 2 required forming groups of 3 participants and we planned the possibility to have groups of 3 male users, or groups composed of 2 male and 1 female user (which corresponds to the 15% proportion of female students in our higher engineering institute).

It was found that the top 4 inventor avatars were perceived as resembling significantly more to inventors ($M = 5.22$; $SD = 1.52$) than the top 4 non-inventor avatars ($M = 2.48$; $SD = 1.36$), $t(56) = 7.21$; $p < 0.001$. In addition, the inventor avatars were perceived as more likely to produce innovative ideas ($M = 4.71$; $SD = 1.48$) than non-inventors avatars ($M = 3.48$; $SD = 1.52$), $t(56) = 3.17$; $p < 0.01$. We also observed that inventor avatars were perceived as more likely to cooperate in brainstorming situation ($M = 4.14$; $SD = 1.48$) than non-inventor avatars ($M = 2.96$; $SD = 1.55$), $t(56) = 2.93$; $p < 0.01$. Conversely, non-inventor avatars were perceived as more sociable and extroverted ($M = 4.67$;

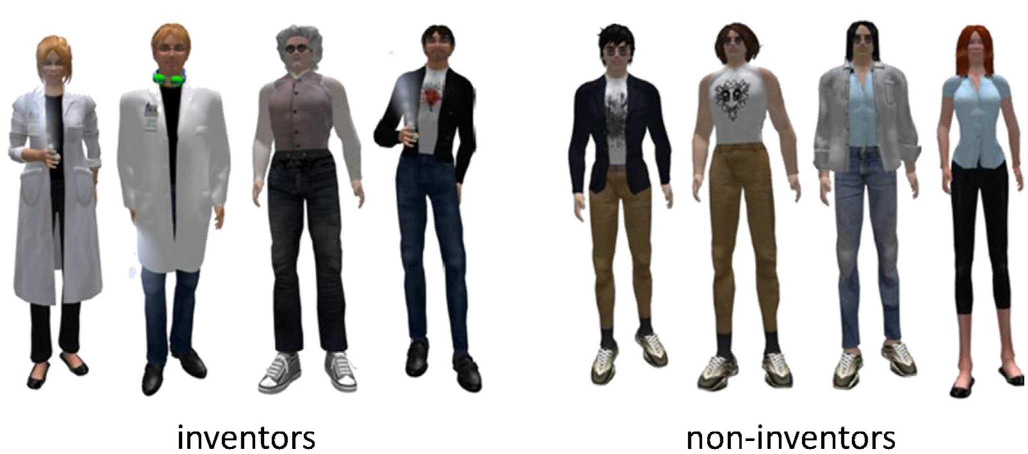

Fig. 2. Final sets of inventors and non-inventors avatars.

$SD = 1.70$) than inventor avatars ($M = 3.62$; $SD = 1.77$), $t(56) = 2.29$; $p < 0.05$. However, non-inventor avatars and inventor avatars did not differ significantly on attractiveness ($M = 3.03$; $SD = 1.68$ vs. $M = 3.07$; $SD = 1.79$), $t(56) = 0.09$; $p = 0.92$.

We may also mention that distractor avatars (colorful and exuberant) and non-inventor avatars did not differ significantly on the items of the creativity-relevant dimension: inventor, $t(73) = 0.01$; $p = 0.98$, innovative ideas, $t(73) = 0.79$; $p = 0.43$, and cooperation, $t(73) = 0.86$; $p = 0.39$.

4.4.2. *Facemash direct pairwise comparison*

The direct pairwise comparison did not lead to exactly the same ranking as the questionnaire but brought out the same pool of avatars: the top 4 inventors and the top 4 non inventors were the same. The avatars which scored high on items of the "creativity" dimension were found at the top of the facemash ranking: responses to item #5 of the questionnaire and ranking results of the facemash are positively correlated ($r = 0.75$; $p < 0.001$). Moreover, facemash scores are positively correlated to the creativity-relevant dimension ($r = 0.77$; $p < 0.001$), but are not correlated to the social and relational dimension ($r = 0.025$; $p = 0.89$). This second assessment tool based on a different method of evaluation strengthens the relevance of the categories identified on the basis of the questionnaire.

4.5. *Discussion*

This preliminary study enabled us to select our final sets of 4 inventor avatars and 4 non-inventor avatars to be used in Study 2. Their perception differs in a meaningful way in terms of creative skills and group collaboration. For engineering students, avatars which look like "inventors" (e.g., looking like Einstein, wearing a lab coat or using scientist' instruments) are perceived as the most creative and seen as the most likely to produce innovative ideas. It is also interesting to mention that the perception of avatars as inventors and the perception of attractiveness are independent. These avatars were used in the Study 2 to test their influence on users' creative performance.

5. Study 2: the influence of avatar appearance on creativity

The goal of this study was to provide a first empirical analysis of the theoretical articulation between the Proteus Effect/self-perception theory and componential theory of creativity. As developed above, we expected that participants, observing their digital appearance ("I embody an inventor"), would make implicit inferences about their creative skills ("I am creative"), and in turn improve their creative performance ("I have lots of/good ideas"). On the basis of Study 1 results, we aimed to test whether inventor avatars enable engineering students to perceive themselves as more creative and exhibit more creative performance. In particular, we expected self-rated creativity to be increased in the inventor condition (Hypothesis H1). Regarding creative performance, we expected that fluency (number of ideas generated) and originality (number of unique ideas generated) would be increased in the inventor condition (Hypothesis H2). Finally, we expected that this effect would endure over time and increase performance in a subsequent face-to-face creativity session (Hypothesis H3).

5.1. *Participants*

Fifty-four participants (9 women, 45 men, mean age $= 23.4$ years old; $SD = 2.7$), all final year students from a higher engineering institute in France, volunteered to take part in this study. None of them had ever used Second Life before the experiment nor participated in Study 1. The participants were arranged into 18 groups of three members, including 1 or 0 female student, to perform collective brainstorming tasks. The groups were composed of students from different classes in order to avoid too much familiarity among group members and simulate in a more realistic way professional ad-hoc creativity groups. They were rewarded course credit for their participation.

5.2. *Procedure*

In line with hypotheses H1 and H2, our purpose was to study the creativity of brainstorming groups in three different Conditions (between-subject variable): in a face-to-face setting (control condition), using neutral avatars (non-inventor condition) or using creative avatars (inventor condition). Moreover, to test hypothesis H3, all groups had to perform a second brainstorming Session in a face-to-face situation just after the first Session (within-subject variable).

All groups worked in the same dedicated room: in the control face-to-face condition, the participants gathered around a table, while in the two avatar conditions, they were installed in three isolated boxes equipped with computers and gathered around a virtual table using their avatars. Avatar attribution was randomized but accounted for users' gender: male participants were randomly attributed a male avatar and female participants were attributed a female avatar. In order to neutralize the effect of the environment, we created a virtual room identical to the real room the experiment took place in (Fig. 3). To preserve anonymity in the two avatar conditions, the experimenters ensured that no prior interaction between participants had happened before the beginning of the experiment: they were welcomed in different parts of the laboratory and taken one by one to their box; they also wore headphones for the entire duration of the experiment.

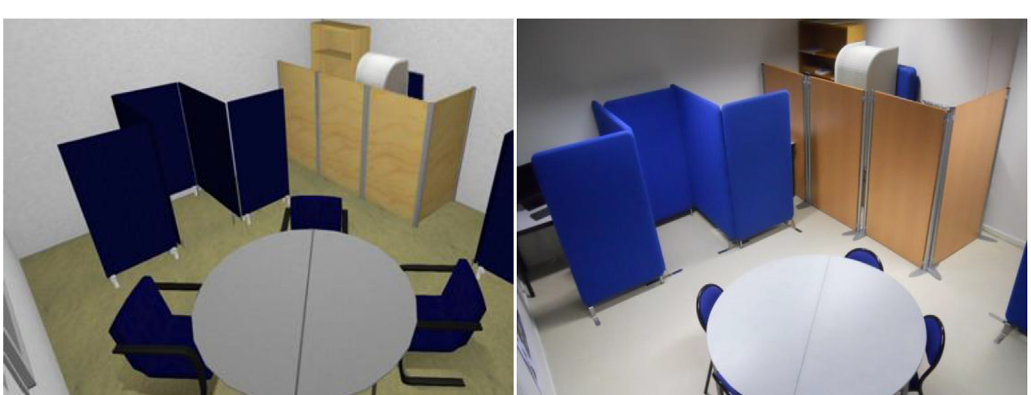

Fig. 3. Virtual and real versions of the experimental room.

In all conditions, participants could only communicate textually: in the control face-to-face condition, they were provided with tablets and keyboards (Fig. 4) to access an instant messaging system and in the avatar conditions they used the built-in Second Life chat. The two avatar conditions began with a tutorial phase during which the participants had to take 1–2 min to observe their own avatar in detail. They were also trained to move in the virtual room and communicate with each other. In this way, the participants also discovered the avatars of all group members.

5.3. Data collected

We collected three kinds of variables:

- Manipulation checks: The questionnaire included some of the questions used in Study 1, in order to measure the creative dimension of their avatar (*My avatar looked like an inventor; My avatar could give innovative ideas;* $r = 0.62$, $p < 0.001$) and its attractiveness (*My avatar was attractive*). We also measured deindividuation (*I could not identify individuals, only their avatar*) as well as presence (*I consider that I embodied my avatar*; *I consider that I was in the same room as my avatar*; $r = 0.35$, $p < 0.05$) in order to check whether they were consistent in the two Second Life conditions or depended on the appearance of the avatar.
- Subjective variables: The questionnaire also included 2 items for the self-assessment of creative performance (*I had lots of ideas; I had high quality ideas;* $r = 0.13$, $p = 0.33$) and an item to evaluate the fun factor (*The system was playful*).
- Creative performance: Creativity was assessed through Fluency and Uniqueness. Fluency corresponds to the number of ideas generated by each participant, after cleaning the corpus from off-task entries (i.e., discussions between participants that do not contain ideas related to the brainstorming task) and from duplicates in each participant's production. Uniqueness is an assessment of originality which corresponds to the number of unique ideas (Torrance, 1966) with regard to all the ideas proposed by all the groups.

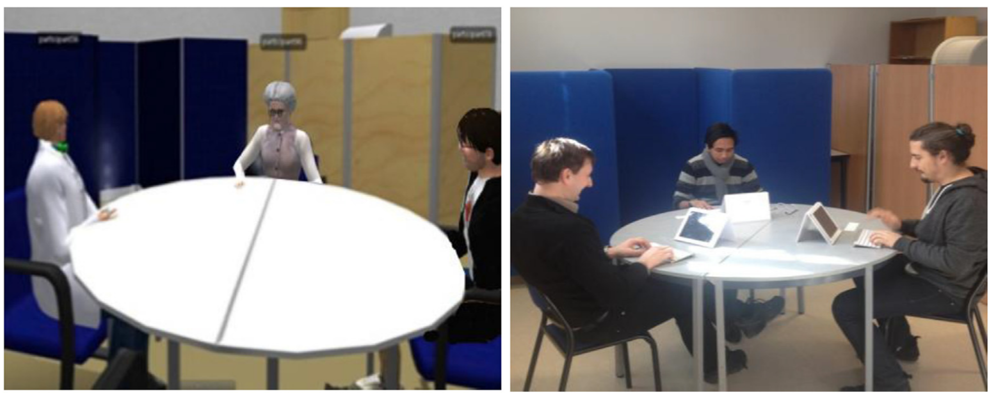

Fig. 4. Brainstorming session in virtual and real environment.

Participants were then presented with Osborn's (1953) brainstorming rules (focus on quantity, withhold criticism, welcome unusual ideas, combine and improve ideas) and asked to perform two successive 15-min brainstorming sessions: the first one through the tablet or through Second Life chat (according to the condition), and the second one in the face-to-face setup, through the tablet's instant messaging system. The two brainstorming tasks concerned a new transportation: Task A *"imagine a crazy solution for traveling on snow, sand or water"* and Task B *"imagine a silent flying public transportation for the future"*. These tasks were presented in a counterbalanced order (see Table 1). They had been designed and pre-tested to be equivalent in terms of difficulty and fluency.

Table 1
Counterbalancing of conditions and tasks addressed in the brainstorming sessions.

	Session 1		Session 2	
	Condition	Task	Condition	Task
Groups 1-3	Face-to-face	A	Face-to-face	B
Groups 4-6	Face-to-face	B	Face-to-face	A
Groups 7-9	Non-inventor avatars	A	Face-to-face	B
Groups 10-12	Non-inventor avatars	B	Face-to-face	A
Groups 13-15	Inventor avatars	A	Face-to-face	B
Groups 16-18	Inventor avatars	B	Face-to-face	A

After each brainstorming, the participants filled out a questionnaire measuring their perceptions of the session and of their avatar (when relevant according to the condition). The whole experiment lasted 50–55 min. Participants were then debriefed, which allowed us to check that they had not understood the goal of the research.

5.4. Results

5.4.1. Manipulation checks

Inventor and non-inventor manipulation checks were compared using a univariate ANOVA. Inventor avatars were better evaluated on the creative dimension (M = 5.02; SD = 1.30) than non-inventor avatars (M = 3.22; SD = 1.26), F(1, 34) = 1,86, p < 0.001). We also observed that inventor (M = 3.55; SD = 1.68) and non-inventor avatars (M = 3.16; SD = 1.54) obtained statistically equivalent scores of attractiveness, F(1, 34) = 0.52, p = 0.47. In addition, deindividuation scores were equivalent in both inventors (M = 6.00; SD = 1.60) and non-inventors (M = 6.11; SD = 1.23) conditions F(1, 34) = 0.05, p = 0.82. The same goes for the presence scores (M = 4.11; SD = 1.40 vs. M = 4.25; SD = 1.52), F(1, 34) = 0.08, p = 0.77.

5.4.2. *Subjective variables*

Subjective variables were processed with a 3 (Condition: control vs. non-inventor avatar vs. inventor avatar) x 2 (Session: session 1 vs. session 2) ANOVA, with Condition as between-subject factor and Session as within-subject factor. Self-assessed fluency showed a significant main effect of the Condition, $F(2, 51) = 8.84$, $p < 0.001$, $\eta^2_p = 0.26$, with a significantly higher score for the inventor condition ($M = 4.61$; $SD = 0.80$) with regard to both the non-inventor condition, $F(1, 51) = 10.95$, $p < 0.01$, $\eta^2_p = 0.18$, and to the control condition, $F(1, 51) = 15.21$, $p < 0.001$, $\eta^2_p = 0.23$, and no significant difference between control and non-inventor conditions ($M = 3.69$; $SD = 1.09$ vs. $M = 3.83$; $SD = 0.97$), $F(1, 51) = 0.34$, $p = 0.55$, $\eta^2_p = 0.00$. The self-assessment of the quality of ideas showed no significant effect. Therefore, Hypothesis H1 was validated for self-rated fluency but not for self-rated quality of ideas.

The evaluation of the fun factor showed a significant main effect of the Session $F(1, 51) = 32.62$, $p < 0.001$, $\eta^2_p = 0.39$, showing that the first session was perceived as funnier ($M = 5.52$; $SD = 1.27$) than the second one ($M = 4.46$; $SD = 1.45$). Moreover, we observed an interaction between Condition and Session $F(2, 51) = 8.34$, $p < 0.001$, $\eta^2_p = 0.24$. Tukey's HSD post-hoc test showed that in the two Second Life conditions (non-inventor and inventor), the first session was rated as funnier than the second one ($p < 0.001$ in both cases, see Fig. 5).

5.4.3. *Creative performance*

The whole corpus was composed of 2340 entries. Once cleaned up from off-task exchanges between participants and from duplicates, we retained 1029 ideas, which corresponds to 28.6 ideas by group or 9.5 ideas per participant for each 15-min brainstorming task. Fluency and uniqueness were processed with the same 3 (Condition: control vs. non-inventor avatar vs. inventor avatar) x 2 (Session: session 1 vs. second 2) ANOVA, but fluency was processed at the individual level whereas uniqueness was processed at the group level.

5.4.3.1. Fluency. The results show a main effect of the Condition, $F(2, 51) = 7.15$, $p < 0.01$, $\eta^2_p = 0.22$. Fluency was significantly higher in inventor avatar condition ($M = 13.08$; $SD = 7.39$) than in non-inventor ($M = 7.88$; $SD = 4.42$), $F(1, 51) = 10.04$, $p < 0.01$, $\eta^2_p = 0.16$, and control conditions ($M = 7.55$; $SD = 2.80$), $F(1, 51) = 11.38$, $p < 0.01$, $\eta^2_p = 0.18$ (see Fig. 6). In addition, the analysis also revealed no main effect of the Session factor, $F(1, 51) = 2.14$, $p = 0.14$, $\eta^2_p = 0.04$, and no significant interaction between Condition and Session factors, $F(2, 51) = 1.62$, $p = 0.20$, $\eta^2_p = 0.06$.

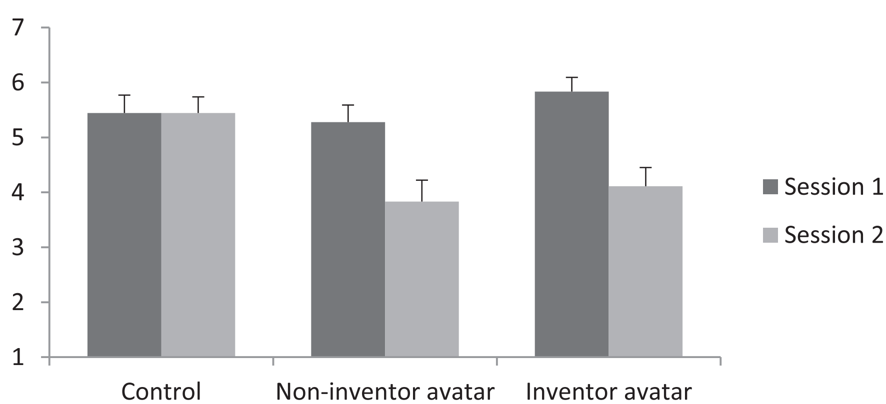

Fig. 5. Mean and standard error of perceived playfulness (fun factor) as a function of the Condition and the Session.

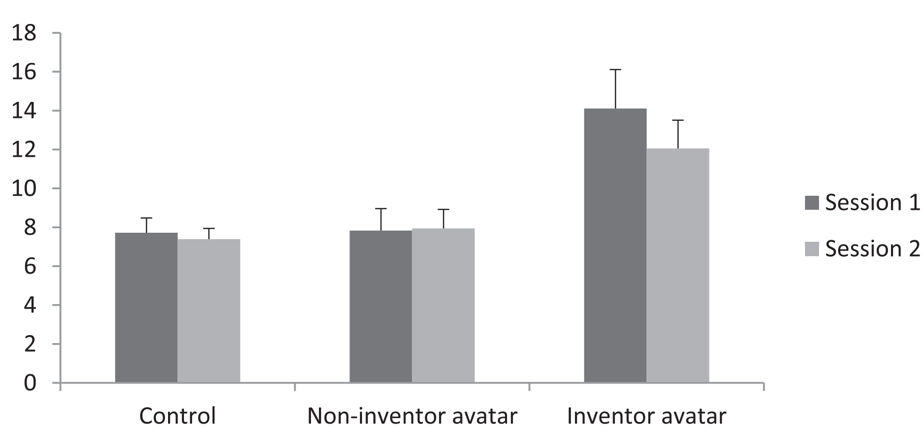

Fig. 6. Mean and standard error of fluency as a function of the Condition and the Session.

To test Hypothesis H2, we examined the effect of the Condition in the first session, and found that inventor avatars ($M = 14.11$; $SD = 8.49$) lead to higher fluency than non-inventor avatars ($M = 7.83$; $SD = 4.79$), $F(1, 51) = 10.06$, $p < 0.01$, $\eta^2_p = 0.16$, and control condition ($M = 7.72$; $SD = 3.25$), $F(1, 51) = 10.42$, $p < 0.01$, $\eta^2_p = 0.17$. Moreover, fluency scores were statistically equivalent in non-inventor avatar and control conditions, $F(1, 51) = 0.003$, $p = 0.95$, $\eta^2_p = 0.00$.

To test Hypothesis H3, we focused on the second session and found the same pattern of results (see Fig. 6). Fluency was higher in inventor avatar condition ($M = 12.05$; $SD = 6.18$) than in non-inventor ($M = 7.94$; $SD = 4.16$), $F(1, 51) = 7.48$, $p < 0.01$, $\eta^2_p = 0.13$, and control conditions ($M = 7.38$; $SD = 2.35$), $F(1, 51) = 9.64$, $p < 0.01$, $\eta^2_p = 0.16$. Moreover, no significant difference was found between the non-inventor avatar and control conditions, $F(1, 51) = 0.13$, $p = 0.72$, $\eta^2_p = 0.00$.

5.4.3.2. Uniqueness. To select unique ideas, we considered the two corpora related to the two brainstorming tasks, which include 532 ideas for task A and 497 ideas for task B. For each corpus, semantic categories were manually annotated by a single judge. In order to test the reliability of this classification, a second independent judge performed the same annotation on 10% of task A corpus and 10% of task B corpus. Inter-judge agreement on this subsample amounted to 77.8%. Uniqueness of ideas was decided with regard to each semantic category: a given idea was considered unique when appearing only once in its semantic category. This procedure led us to identify 212 unique ideas (123 for task A and 89 for task B), which corresponds to 20.6% of the corpus. Examples of unique ideas can be found in Table 2.

Table 2
Examples of unique ideas.

Task A *("imagine a crazy solution for traveling on snow, sand or water")*	Task B *("imagine a silent flying public transportation for the future")*
- A system creating a mountain under your feet	- Making people live in orbit
- A personal gravitational field to remain stable	- Swallowing helium
- Inflatable wheels to float on snow and water	- Creating a second earth surface above the current one
- Covering water and snow with glass	- Soap bubbles
- Creating a temporary transformation of the ground when you walk on it	- A toboggan network
- A submarine digging galleries in the sand like a mole	- Traveling through giant coils with metal suits, using the magnetic field
- An exoskeleton adapting to the external environment	- Jumping from one building to another and sticking on the walls
- Horizontal quicksand: instead of swallowing you down to the ground, they pull you to your destination	- Dematerializing everybody as in Matrix
- By creating antimatter	- A time machine for traveling a few hours back and overcoming the rotation of earth, so that people find themselves on another continent without having moved
- A floating centipede	- A giant hippity-hop

The results show a significant main effect of the Condition factor on the number of unique ideas, $F(2, 15) = 9.50$, $p < 0.01$, $\eta^2_p = 0.56$: the inventor condition ($M = 9.58$; $SD = 4.39$) produced significantly more unique ideas than the control ($M = 4.41$; $SD = 2.50$), $F(1, 15) = 12.22$, $p < 0.01$, $\eta^2_p = 0.45$, and non-inventor conditions ($M = 3.66$; $SD = 2.57$), $F(1, 15) = 16.03$, $p < 0.01$, $\eta^2_p = 0.52$, while there was no significant difference between control and non-inventor conditions, $F(1, 15) = 0.25$, $p = 0.61$, $\eta^2_p = 0.01$. The main effect of Session appears non significant, $F(1, 15) = 0.01$, $p = 0.91$, $\eta^2_p = 0.00$, as the interaction effect of Condition and Session factors $F(2, 15) = 1.48$, $p = 0.26$, $\eta^2_p = 0.16$.

To test Hypothesis H2, we examined the effect of the Condition in the first session, which shows that groups tended to produce more unique ideas in the inventor condition ($M = 8.33$; $SD = 4.17$) with regard to the non-inventor condition ($M = 4.33$; $SD = 2.50$), $F(1, 15) = 4.14$, $p = 0.06$, $\eta^2_p = 0.21$ or the control condition ($M = 4.83$; $SD = 3.31$), $F(1, 15) = 3.17$, $p < 0.09$, $\eta^2_p = 0.17$. The control and non-inventor conditions did not differ significantly, $F(1, 15) = 0.06$, $p = 0.80$, $\eta^2_p = 0.00$.

To test Hypothesis H3, we focused on the second session and observed that the number of unique ideas was higher in the inventor condition ($M = 10.83$; $SD = 4.62$) with comparison to the non-inventor condition ($M = 3.00$; $SD = 2.68$), $F(1, 15) = 17.83$, $p < 0.001$, $\eta^2_p = 0.54$, or the control condition ($M = 4.00$; $SD = 1.54$), $F(1, 15) = 13.57$, $p < 0.01$, $\eta^2_p = 0.47$. No significant difference was found between the non-inventor and control conditions, $F(1, 15) = 0.29$, $p = 0.59$, $\eta^2_p = 0.02$.

Finally, the two creativity measures (Fluency and Uniqueness) proved to be positively correlated, both in session 1 ($r = 0.77$, $p < 0.001$) and in session 2 ($r = 0.90$, $p < 0.001$).

5.5. Discussion

Brainstorming in a virtual environment shows a strong potential for generating ideas in remote groups. In this second study, groups working together through Second Life and using neutral avatars performed as well as groups in co-presence. This sole result may already provide a valuable insight to extended enterprise issues and inspire news ways of cooperating remotely, complementary to widely used communication facilities such as videoconferencing. Moreover, the use of a virtual environment influenced the relative level of fun experienced by participants: those who performed the first brainstorming virtually then rated the face-to-face, tablet-supported situation (which simulates a classical electronic brainstorming system), as significantly less funny than the virtual condition. The fun factor being likely to foster engagement of co-workers, it may also be considered in the choice of collaborative tools, in particular for extended companies.

Beyond the use of virtual environment, the main result of this study concerns the impact of avatars' appearance on the creativity of brainstorming groups. The manipulation checks enabled us to confirm that the two avatar conditions (inventor and non-inventor) differed only with regard to the creativity-relevant dimension: inventor avatars were perceived as more creative but did not differ in attractiveness and did not impact deindividuation and presence scores. Embodying inventors (which are creative avatars for the target population) produced a series of consistent effects on the creative performance: it increased fluency (i.e. number of ideas), originality (i.e. number of unique ideas) and self-assessed fluency, which means that the participants also felt more creative when using inventor avatars. Moreover, participants who had used inventors in the first session continued being more creative in the subsequent face-to-face session.

With regard to the componential theory of creativity (Amabile, 1983, 2013), our results suggest that Creativity-Relevant Processes can be almost instantly leveraged through the Proteus Effect, which sheds a new light on creativity processes. Indeed, from a theoretical point of view, Creativity-Relevant Processes are a relatively stable component (e.g. personality characteristics, cognitive styles), which has to be trained to be enhanced. Our results show that it can also be improved by a relevant self-representation in the immediate task context. However, one could consider that one limit of our implementation of the Proteus Effect lies in the choice of inventor avatars, which entangle both Creativity-Relevant Processes ("I embody a creative person"), as checked in the two studies, and Domain-Relevant Skills ("I embody a good engineer"). This would question the possibility of contextually increasing the Creativity-Relevant component. To support our interpretation, we may highlight that we implemented only the ideation phase of the creative process (i.e. the Response Generation; Amabile, 1996). According to the componential theory of creativity, Domain-Relevant Skills are seen to impact the Preparation and Response Validation steps, but not directly Response Generation. In sum, we believe that we managed to contextually improve Creativity-Relevant Processes through avatars' appearance.

That said, if the influence of avatars as been empirically established in the framework of the Proteus Effect (Yee & Bailenson, 2007), the underlying mechanisms may also involve priming processes (Peña et al., 2009). According to Bargh, Chen, and Burrows (1996), *Priming* refers to "*the incidental activation of knowledge structures, such as trait concepts and stereotypes, by the current situational context*" (p.230). Indeed, because cognition is organized in memory as a structure of knowledge, the mere activation of a concept/stereotype in a given context may activate some associated semantic information networks. For instance, perceiving a soccer hooligan can activate some related concepts (e.g., aggressiveness, violence) as well as inhibit more distant concepts such as intelligence, friendliness and so on (Dijksterhuis & van Knippenberg, 1996). Moreover, these situational cues may lead to behavioral assimilation, i.e. an increase in the likelihood of behaviors congruent with the primed concept. In an automatic and unconscious way, individual's behavior is influenced by the concepts that the situation activates (e.g., Bargh et al., 1996; Dijksterhuis & Van Knippenberg, 1998). Following this perspective, the avatars (of self and of the other users; Yee & Bailenson, 2009) could be seen as a priming support that may lead to behavioral assimilation (Peña et al., 2009; Peña, 2011). The theoretical foundations of the Proteus Effect/self-perception and Priming processes are both compatible with the componential theory of creativity since priming concepts congruent to Creativity-Relevant Processes may lead to increased creative performance through behavioral assimilation. Disentangling these concurrent processes and estimating their relative contributions to avatar-mediated creativity offer challenging perspectives for further research.

6. General conclusion

This article aimed to examine the potential of avatars for improving Creativity-Relevant Processes and creative performance. As hypothesized, our results show that creativity can be stimulated through the use of relevant avatars. In this research, we simulated the Response Generation, or diverging phase of the creativity process. In a real-world scenario, we may either extend the use of avatar-mediated creativity to the whole process (including the upstream Preparation phase and the downstream convergent phase of Response Validation; Amabile, 1996) or articulate real and virtual creative steps. For example, many companies or consulting agencies use creative rooms: avatar-mediated creativity platforms could be a complementary/alternative and cost-effective solution in the creative process. Moreover, collaborating through a virtual world opens the possibility to seamlessly integrate geographically distant participants, which is a growing demand of extended enterprises. Beyond distributed work, we may underline that the effects we observed in this research could also benefit to teams of people who are used to working together face to face. Indeed, masking group members' identities through avatars is also likely to create new dynamics, which could be very useful to address innovation problems with a new viewpoint and/or change routines and habits among regular coworkers (e.g. hierarchical asymmetry, interpersonal relations, leadership).

This research was conducted with a population of engineers and could be extended to different populations with different norms and goals related to creativity. For instance, in the field of fashion or fine arts, the creative digital self-representation could be more "eccentric" – exuberant and colorful – than the inventor avatars prevailing for engineers. Likewise, it could be interesting to allow users from specific professions to embody an iconic expert or creative figure in that field. These might include for example Leonardo da Vinci, Thomas Edison (for engineers), Pablo Picasso, Vincent van Gogh (for painters), Yves Saint Laurent, Jean-Paul Gautier (for fashion designers) and so on. These avatars of iconic experts may also be used in interaction contexts in order to study the contrast effect (Leding, Horton, & Wootan, 2015) between avatars and improve the perceived unicity of user's avatar.

Beyond the visual features of avatars, the whole virtual environment could also be used in order to improve creative performance. Indeed, the environment – through the various cues involved in the situation – can also prime concepts and influence cognition and behavior. For example, Kay, Wheeler, Bargh, and Ross (2004) have shown that the mere exposure to objects related to business (i.e., a briefcase, a boardroom, tables, a fountain-pen) leads to the cognitive activation of competition and to less cooperative behavior. A recent study by Peña and Blackburn (2013) provides a first illustration of this kind of phenomenon in virtual environments. In this experiment, the authors manipulated the virtual context in which users interact (a library vs. a coffee shop). The results showed that the virtual environment influence behavior and mutual perceptions of interlocutors congruently with the primed concepts. From there, it could be possible to design virtual scenes that are conducive to increased creative performance in groups, whose characteristics are tailored to the representations of specific user populations (Nelson et al., submitted). As a consequence, the configuration of virtual environment – via the activation of concepts supported by contextual cues – could be used strategically to foster creativity. Moreover, because avatars are intended for being integrated in a virtual world, the potential interaction between avatars and virtual scenes then becomes a key issue. Since a given avatar could be differently perceived in different environments, this interaction may become a new line for further investigation.

Furthermore, in the case of collaborative creativity, analyses of the environment and of the avatars could be articulated to group processes. In particular, it has been shown that specificities of Computer-Mediated-Communication (i.e., visual anonymity and isolation) can stimulate group processes, particularly depersonalization, group identification and the influence of social norms (e.g., Postmes, Spears, & Lea, 1998, 2002; Postmes, Spears, Sakhel & de Groot, 2001). Since these phenomena also occur in virtual worlds (Guegan, Moliner, & Buisine, 2015), the similarity of avatars among group members (through physical appearance, collective symbols, or costumes) may support identification to and positive valuation of the group (Guegan, Moliner, et al., 2015; Kim, 2011; Lee, 2004). This kind of processes, based on a social identity approach of deindividuation, could be a relevant means to foster group cohesion (Postmes et al., 1998), improve equity of collaboration and reduce social loafing (Harkins & Szymanski, 1988). Therefore, the influence of virtual worlds — through environment design and avatars' appearance — on group climate and collaborative performance opens new research perspectives.

In sum, the use of virtual tools for creative activities leads us to consider at least three kinds of factors: the appearance of avatars, the virtual environment as a work context, the collaborative processes among users and the combined influence of these three factors. Further research is now required to cover the whole complexity of such a cybercreativity-based analysis of virtual worlds.

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