Inspiring Social Creativity in Children with CUBUS

Patrícia Alves-Oliveira[*]
University of Washington & INESC-ID
USA, Portugal

Raquel Oliveira
ISCTE-University Institute of Lisbon
Portugal

Patrícia Arriaga
ISCTE-University Institute of Lisbon
Portugal

Ana Paiva
Instituto Superior Técnico,
Radcliffe Institute for Advanced Study, Harvard University
Portugal and USA

Carlos Martinho
Instituto Superior Técnico
Portugal

Abstract

Although creativity is an ability that can be developed if trained, most of the systems developed for creativity stimulation focused on individual interventions. This work presents the design, development, and evaluation of CUBUS, a digital tool developed to inspire social creativity in children through storytelling and emotionally expressive characters. Groups of children collaborate with the autonomous virtual characters of the digital tool to create a story together. Our main goal was to conduct an experimental study (n=20) to investigate if the interaction between children and the autonomous emotionally expressive virtual characters present in CUBUS can stimulate social creativity during a storytelling activity. We measured the impact of the digital tool across several creativity domains: pre-and post-testing (questionnaire assessment), the creative process of children (behavior analysis), and the story created (creative outcome). Results showed that although children generated fewer storytelling ideas using CUBUS, these ideas were deemed more original.

Introduction

Despite the major role of creativity in our lives, including being paramount for our professional success and well-being, it is often overlooked and unappreciated. Although some schools feature activities that foster creativity, such as theater or painting, they appear as scarce and often times are not deemed mandatory. The mere time for playing, a precursor time for imagination and creative thought, is being reduced from children's lives (Elkind, 2008). This shows how children's curiosity and creativity tend to be dismissed starting in early school years (Kim, 2011). The formal organization of schools (e.g., reinforcing behaviors such as staying seated for extended periods and performing large amounts of school homework), seems to be driving the creative growth of children outside of the schools more than inside its walls (Csikszentmihalyi, 1996; Runco, Acar, and Cayirdag, 2017). It becomes thus necessary to find new ways to honor creative spaces at school.

An important aspect of fostering creativity at school is to endow teachers with the necessary tools and support to accomplish this task. Although many schools already feature storytelling activities that help promote children's creative thinking (Di Blas, Paolini, and Sabiescu, 2010), these activities are cumbersome for teachers to prepare and manage, not to mention they are scarce (Chan and Yuen, 2014). With this work, we aim to contribute to current creativity support tools with the design of CUBUS, which consists of a digital environment platform with emotionally expressive characters for storytelling activities. CUBUS can be used in any compatible tablet or iPad, as children seem to show an interest in using electronic devices from a young age (Salonius-Pasternak and Gelfond, 2005). The novelty of CUBUS is the presence of emotionally expressive autonomous virtual characters that hint at new storylines that would not emerge otherwise. To develop this digital tool, we included children as design partners, testers, and users who lead the design, improvement, and evaluation of this tool in terms of its impact on their creativity.

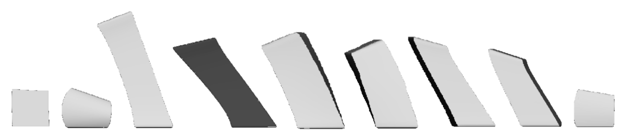

Figure 1: Keyframes of the animation of a character from CUBUS designed with Autodesk Maya®.

Our ultimate goal was to investigate if the interaction between children and the autonomous emotionally expressive virtual characters present in the digital tool can stimulate social creativity during a storytelling activity. CUBUS shows promises to be used in education environments, such as the school, and for any collaborative play environment of children, such as their home.

Background

This section provides a background on the topics of social creativity and the role of emotions in creativity. We reviewed these concepts as they informed the design and development of our digital tool.

Social Creativity

Researchers have different viewpoints as to what creativity is (Kampylis and Valtanen, 2010) with the agreement over

[*]Email: patri@uw.edu

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this concept changing over time (Sternberg and Sternberg, 1999). While earliest definitions of creativity described this ability as a function of an individual (Guilford, 1967), creativity has been defined considering more than just the isolated individual nature and expertise to be seen as a social construct (Plucker, Beghetto, and Dow, 2004). The focus of this work will be on social creativity, also described as distributed creativity (Sawyer and DeZutter, 2009). This particular aspect of creativity is related with solving problems and creating new solutions collectively. Social creativity is crucial to be studied, since "much of the human creativity arises from activities that take place in a social context in which interactions with other people and the artifacts that embody group knowledge are important contributors to the process" (Fischer et al., 2005). This corroborates that creativity does not occur strictly within each individual but also through our interactions with each other when pursuing a common focus (Csikszentmihalyi, 1996).

As human beings are social by nature, it is therefore expected that a significant part of our thinking and problem solving emerged collaboratively (Fischer et al., 2005). For social creativity to unfold, there are some requirements that need to be met, such as the degree of task complexity which should account for some uncertainty as a way of generating discussions and collaborative solutions; it is equally important that the task is unscripted and that it allows for experimentation, so that improvisation and flow come into the creative process (Fischer, 2007). In our work, we relied on these principles and chose a storytelling task as it denotes some structure, accounting for the existence of characters, action, and a scenario, and is anchored on a starting, middle, and ending plot stages. At the same time, the open-ended nature of a story provides children with the right amount of uncertainty to create storylines together.

Emotions in Creativity

According to Hutton and Sundar (2010), games created with the goal of increasing creativity have much to gain from featuring interactions that are rich in emotional expression. Different levels of emotional arousal impact creativity. While higher levels of arousal tend to hinder the creative process as they reduce the capability to perceive, process, and evaluate new information (St-Louis and Vallerand, 2015), moderate levels are helpful when gathering information to create novel ideas since they enhance cognitive flexibility and help to stay focused during the task. Additionally, a "boomerang effect" of arousal is found to be detrimental in divergent thinking tasks, as moderate levels of arousal (rather than extremely low or high levels) are necessary for engagement in divergent thinking performance (De Dreu, Baas, and Nijstad, 2008).

As emotional expression provokes creativity, we have incorporated the idea of emotionally expressive virtual agents in our digital tool. These characters favor moderate emotional arousal levels that are reported as beneficial to stimulate creativity, rather than extreme emotional reactions.

Figure 2: *Left:* Emotions of the Inside Out movie characters and their predominant color. *Right:* Virtual characters designed and developed within this work that match the colors of the emotions of the movie Inside Out.

Digital Tools for Creativity

There are a few digital platforms developed that closely relate to creativity applications. Hornecker and Stifter (2006) developed tangible interfaces to engage visitors in a museum experience. Their main findings indicated that engagement is fostered between the museum audience and the tangible experience if the system can accommodate group interactions, as most museum visitors come in groups. Additionally, Snibbe and Raffle (2009) created guidelines for designing users' interactions with social immersive media, which include narrative models that highlight the power of 'users as actors' to promote natural and engaging interactions. Additional work on prolonged engagement with digital media and museums exhibits was conducted (e.g., Humphrey and Gutwill (2017)), and a common theme is to place the users as the active (and not passive) part of the experience. The incorporation of storytelling in digital interactive systems showed that such systems can create a medium for collaborative creative expression between the users and the system itself, especially when the system can convey emotions by making use of colors and animations (Long et al., 2017), similarly to what we incorporated in this work.

CUBUS: Our Digital Tool for Creativity

In this section, we provide details about CUBUS, the digital tool that we created[1]. CUBUS consists of a virtual environment that can be accessed using an iPad or Tablet and enables children to build stories using cube-shared characters. These virtual characters are designed to be emotionally expressive and CUBUS is intended to foster social storytelling experiences for children. In this section, we provide details about the design of the virtual characters and the virtual world of CUBUS.

Emotionally Expressive Characters for Creativity

The virtual agents that act as autonomous characters in the story are one of the most innovative parts of this work as they were designed to be the stimuli that would foster children's creative process during storytelling. To avoid the uncanny valley effect (Ciechanowski et al., 2019), especially concerning artificial emotion expression, the design of these characters' space revolved around non-humanlike characters (Tinwell et al., 2011). Therefore, the characters are

[1]A tutorial video about CUBUS – our digital tool can be accessed through this weblink: `https://www.youtube.com/watch?v=Tuj5-27fqwY`.

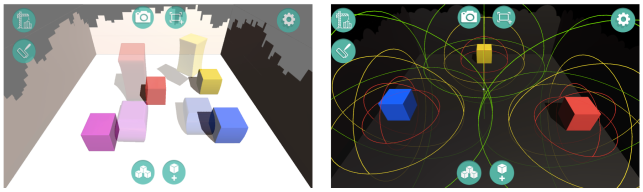

Figure 3: *Left:* Virtual environment with an active overlay from the stop-motion technique, to illustrate where the last photo was taken and facilitate the understanding for children about where the character will be placed in the next position. *Right:* Proxemics that weigh the characters' interactions, defined in green as the social space, in yellow as the personal space, and red as the intimate space (Hall, 1966). The parameterization of proxemics enabled the characters to interact with themselves in a socially appropriate manner. For example, if a character is in an intimate space zone with another, they start interacting by expressing their emotions, instead of ignoring the presence of each other as it occurs when they are in the social space.

shaped in the geometric form of *a cube*. This format of characters has several advantage points, namely avoiding stereotyped ideas about gender, role, and behaviors and leaving the storytelling more open to children's ideas. Additionally, it is well known from previous research that humans can create complex stories with abstract shapes, such as triangles and rectangles, which supports our design choice (Heider and Simmel, 1944).

The characters make use of minimal interaction modalities, such as colors and movements to express emotional states. It is well established the relation between color (Gilbert, Fridlund, and Lucchina, 2016; Sutton and Altarriba, 2016) and movement (Wallbott, 1998; Camurri, Lagerlöf, and Volpe, 2003) in emotions. The colors for each emotion expressed by the characters followed studies about color-emotion association models (Terwogt and Hoeksma, 1995; Hemphill, 1996; Nijdam, 2009; Terada, Yamauchi, and Ito, 2012; Baraka, 2016) and were inspired in filmmaking through the Pixar®animation movie "Inside Out". We have chosen this movie as an inspiration as Paul Ekman was the scientific consultant for the design and creation of the movie characters' whose role is to represent emotions (Keltner and Ekman, 2015). Ekman's insights for color-emotion-behavior mapping for Inside Out overlaps with previously referred models, e.g., similarly to Terada, Yamauchi, and Ito (2012)'s model, anger is represented as red and joy as yellow, providing scientific ground to this source of inspiration. As such, we considered that the unique colors and behaviors associated with each emotion would create distinguishable and appropriate emotions for each of our characters (see Figure 2).

The virtual agents' design followed Disney®animation principles to provide the "illusion of life" of the characters (Thomas, Johnston, and Thomas, 1995). From the twelve established animation principles, we have chosen four that could be transferred to our characters. These are *squash and stretch* (characters squash and stretch deforming their initial form while maintaining the same volume), *anticipation* (anticipating movements and actions that inform what the character is going to do next), *follow-through* (this principle works as an opposite of Anticipation. When a character stops doing something, it should not stop abruptly, for that causes an unnatural feeling; this animation is generally associated with inertia but can also be used to emphasize the stop), and *staging* (related to the general set-up in which the character expresses itself; this principle is related to making sure that the expressive intention is clear to the viewer. Some ways of accomplishing this are by positioning lights, camera, music, characters, and surrounding objects). We used the Autodesk Maya®, a 3D animation software application, to create animations for the virtual agents.

Since emotions tend to enhance creativity in video games (Hutton and Sundar, 2010) it was important to establish the most appropriate emotions to model the characters. We used Ekman's model of basic emotions and included *happiness, anger, sadness, fear, and disgust* to develop in the characters (Ekman, Friesen, and Ellsworth, 2013). Surprise emotion was removed given its ambiguous interpretation in terms of valence and associated age-differences in its perception (Tottenham et al., 2013; Jack, Garrod, and Schyns, 2014; Shuster, Mikels, and Camras, 2017). Each emotion has a unique appearance and means of expression, detailed below (see also Figure 1).[2]

Happiness — Characters featuring happiness express fast and expansive movements, such as jumping or dancing. These animations resemble positive and playful actions, such as spinning jump, inspired in a celebration. The color of happiness is yellow;

Anger — Characters featuring anger convey an aggressive movement. They stretch their bodies and mimic an inflated chest while leaning forward and keeping the tension in the character's body. The color of anger is red;

Sadness — Characters featuring sadness express slow and contained movements, such as appearing contracted with their "head" hanging low giving the impression of being looking at the floor. This character can whimper to mimic crying. The color of sadness is blue;

Fear — Characters featuring fear quickly retract, crouch, and hide. While crouching, the characters start twitching and shaking in fear. The color of fear is pink;

Disgust — Characters featuring disgust appear as looking away and avoiding contact. This effect was emulated by having the character retracting and turning away, giving the impression that "it cannot look to a disgusting stimulus" before reluctantly turning back to its original direction. The color of disgust is green.

Characters express their emotion more intensively according to the distance they have from each other (what is called

[2]The design and behavioral expression of each of the characters' emotions is also detailed in a video that can be accessed through this weblink: `https://www.youtube.com/watch?v=oDAm__9eyjw`.

proxemics) (Hall, 1966). This parametrization was developed in order to create the behavior of the characters more complex in terms of their emotional expression, i.e., a character that is closer to another has a stronger emotional expression and the degree of expression decreases as characters are further away. This behavior was designed to mimic the lower/higher perception of emotions with distance (see Figure 3 on the right for a representation of proxemics). While using CUBUS children can add, remove, or hide characters for their story. This can be performed using a dedicated menu on the interface. The characters can be moved around the virtual world using drag-and-drop, a traditional feature that exists in most digital devices.

Virtual World for Storytelling

The virtual world of the digital tool supports children's creative storytelling process through the use of components such as background personalization, stop-motion technique, and intertitles. Specific features of the world are detailed below.

Backgrounds — Background's shapes and colors can be customized according to the story children want to create. Background can vary from curvilinear, rectilinear, or spiky. A color palette was enabled, and the background can be adapted to any color (e.g., to simulate the different phases of a day, weather conditions, or environments) (Ware, 2012) (see Figure 4);

Stop-motion — The digital tool supports the stop-motion technique for storytelling as children can record the story they create. While they create the story, children perform screen captures that are stored in the digital tool. In a later stage, these frames are transformed into a movie that allows for narration (see Figure 3);

Intertitles — Intertitle screens can be incorporated at any moment of the story, similarly to their usage in silent movies (see Figure 4).

Experimental Study

This section presents the experimental evaluation to investigate the impact of the digital tool in stimulating creativity in children. Therefore, the research question for this study was: *can the interaction between children and the autonomous emotionally expressive virtual characters present in the digital tool, stimulate social creativity during a storytelling activity?* To answer our research question, two study conditions were considered:

- **Experimental condition:** Small groups of children created a story using the digital tool, featuring autonomous and emotionally expressive virtual characters;
- **Control condition:** Small groups of children created a story using CUBUS, but its characters *did not* display any behaviors.

Given that emotions positively influence creativity expression (Hutton and Sundar, 2010), we hypothesize that children in the experimental condition will score higher in

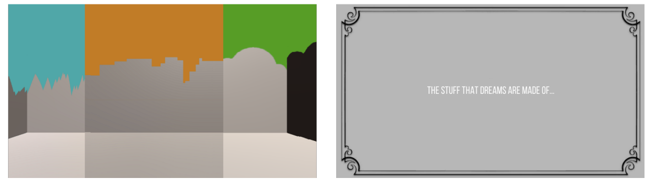

Figure 4: *Left:* Background shapes available in the system in some customizable colors. *Right:* Example of an intertitle screen produced by children where is written "The stuff that dreams are made of..."

creativity levels compared to children in the control. Children's creativity levels were measured in terms of their *creative process* during story creation (measured through behavior analysis using the recordings of the sessions), their *creative product* (the final story created by children was evaluated with external judges experts in the field), and the impact in their creativity skills, often called *creative person* in creativity research (measured with a creativity validated test as a pre- and post-test evaluation). By measuring the impact of CUBUS across these different domains of creativity, a deeper understanding of the impact of interacting with emotionally expressive autonomous agents in creativity is acquired.

Participants

A total of 20 children participated in the final evaluation of the system. Children ages ranged from 7 to 9 years old (*M* = 8.10, SD = 0.72, 14 female). This study was performed in the classroom of a school and children performed the task in pairs chosen by the school teacher, therefore, each session consisted of 2 children in a total number of 10 sessions. Each session lasted approximately one 1-1:30hours. The difference in the length of the session is attributed to the time that children took while creating the story, which was not restricted.

Materials

CUBUS was used to perform the storytelling activity and run on an Android tablet. We also used voice recordings of children to collect data about the creative process of storytelling.

Measures

In this section, we detail the measures used to evaluate the creative person (creative skills of children), creative process (final story movies), and the creative process (story creation).

Creative Person. We used the Test for Creative Thinking-Drawing Production (TCT-DP) test to measure the creative potential of children. TCT-DP is a well-established test in the field of creativity, applicable to a broad age range, culturally fair, and helps to identify high creative potentials as well as low creative, neglected, and poorly developed ones (Jellen and Urban, 1986; Urban, 2005; Jellen and Urban, 1989). A version of the test adapted to the Portuguese population was used (Nogueira, Almeida, and Lima, 2017). TCT-DP is composed of Forms A and B and consists of a sheet of paper with six graphic elements, named fragments, of a circle, a dot, a dashed line, a 90-degree angle, a curved line, and a small open square. These are placed at fixed and pre-established locations on the page. All of the elements, except for the small open square, are enclosed in a large rectangular frame, and this forms a short of an incomplete drawing. According to the manual, participants are instructed to "complete the drawing initiated by an artist" and to "give a title to the drawing when completed". The final drawings made by children were scored according to the 14-point scoring system (Urban, 2005) and a trained psychologist that underwent TCT-DP training scored each drawing. The specific criteria used to code the drawings and the detailed application instructions can be found in the Supplementary Materials of this submission.

Creative Process. The creative process of children was evaluated using a deductive content analysis approach and inter-rater reliability was established and a coding scheme was developed. To do this, two psychologists blinded to the hypothesis of the study analyzed the video recordings of children creating a story and established categories. Disagreements were settled by several joint discussions and adjustments to the criteria for each category. The final coding scheme was used to analyze the interactions and the ideas generated during the creative process. This coding included three broad categories related to creativity: fluency, flexibility and elaboration, and originality[3]. Agreement rates were calculated separately for each dimension of the coding scheme. Overall, the inter-coder agreement was high, varying between 0.76 and 0.95 ($M = 0.87$), indicating an excellent level of agreement according to statistical standards (Bakeman and Quera, 2011).

Creative Product. The final short stop-motion movies created by children were evaluated using the Consensual Assessment Technique (CAT), which relies on ratings given by a panel of independent expert judges (Hennessey, Amabile, and Mueller, 1999). In the case of this study, the panel of external judges consisted of experts of cinema and animation ranging from movie directors, producers, animators to cinema college teachers. We identified these judges by performing an online search using Google Search Engine for local cinema-related activities, using the keywords of cinema festivals for children, animation festivals, cinema schools, and cinema universities. We then established contact via email to understand their availability to participate as judges and, upon their agreement, each judge rated 10 movies, 5 from each test condition. Their coding was individual and blinded to the study condition. To eliminate order effects for movies' assessment, we used the Latin square technique (Winer, 1962) to randomize the questionnaires' version when the judges opened the link provided. This evaluation was performed through an online questionnaire using Google Forms containing children's movies accompanied by a scale which allowed rating them, as dictated by CAT. Our final panel of judges, i.e., judges that finalized the evaluation of all movies, was composed of 9 participants, aged between $19-54$ years old ($M = 42.00, SD = 10.10$, 7 male). Given that the assessment is performed with experts in the field, small samples such as $5-10$ experts is accepted in the literature (Hennessey, Amabile, and Mueller, 1999).

[3]Details about the coding scheme are present in this weblink: `https://osf.io/6cv93/?view_only=2c002947ad8046a0afa54b7a5ee4f5a9`.

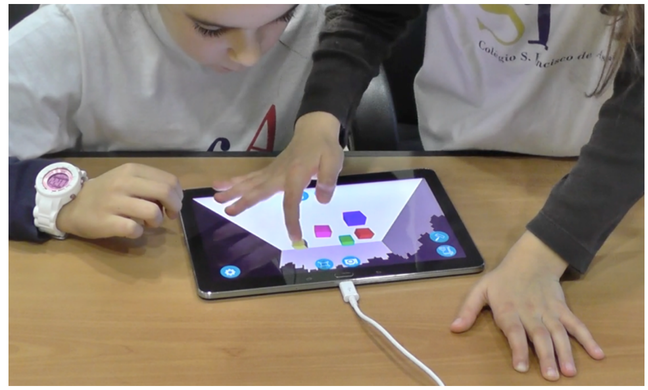

Figure 5: Children interacting with CUBUS, the digital tool for creativity inspiration.

Procedure

Pairs of children entered the designated classroom where the study was performed (see Figure 5). The groups of children were chosen by the teacher. Two researchers (one psychologist and one computer scientists) were involved in conducting this study. Children started to create their story collaboratively by adding characters and personalizing their scenario/background. The last stage of this study consisted of watching the movie with the children and congratulating them on their accomplishment.

Results

This section details the results regarding the creative person, process, and product.

Creative Person

Shapiro-Wilk test for normality revealed a normal distribution for TCT-DP Form A, $p > 0.05$, and a non-normal distribution for Form B, $p < 0.05$. To assess if the sample was homogeneous in terms of creativity skills before the intervention as a baseline measure, we computed the results of the pre-test (Form A) between conditions, and no significant differences between creativity skills in children allocated in the experimental and control conditions $t(18) = 0.872, p = 0.394$, revealing a similar creative potential of our participants. To measure if the intervention had an effect on the creativity skills of children we compared the results from the post-test (Form B) and concluded that there is a borderline significant effect between conditions, $U = 24.500, p = 0.053, r = 0.4$, with children showing higher creative skills in the experimental condition ($Mdn = 13.05$) compared to the control condition ($Mdn = 7.95$). Overall, this result did not support the hypothesis which postulated that creative levels of children would be higher in the experimental condition.

Creative Process

The story creation process lasted, in average, 30 minutes ($M = 29.67, SD = 8.33, min = 21.35, max = 47.18$) and resulted in the generation of an average of 174 ideas per session ($M = 174.40, SD = 68.44, min = 100, max = 333$). To evaluate the effects of the manipulation in the children's creative process, we performed a between-groups analysis by calculating the rate of ideas generated per category of the coding scheme considering different storytelling stages[4]. In particular, we used three continuous but mutually exclusive storytelling stages, namely rising action (starts at the beginning of the interaction and ends when the characters in the story enter the main action), climax (from the ending of falling action until the moment when the characters finish the main set of actions), and falling action (comprises interactions occurring afterward until the end of the story) (Freytag, 1896). To calculate these rates and to accommodate for the group nature of the interaction, we considered the number of ideas produced by the group (and not the individual) as a unit of measure of social creativity. To analyze the difference in the rates of ideas belonging to each storytelling stage, we conducted an independent samples t-test in which we compared the ratio of ideas in each story-building stage between the two conditions.

During the climax stage, we found a difference in fluency between conditions, $t(8) = -3.23, p = 0.01, d = 2.01$, with the control condition showing a higher rate of relevant ideas generated ($M = 0.37, SD = 0.04$) compared to the experimental condition ($M = 0.23, SD = 0.09$). We did not find additional results for rising action and falling action between conditions. In addition, we observed significant differences between conditions in the fluency regarding ideas generated for the characters, $t(8) = -4.01, p = .004, d = 2.75$, with participants in the control condition generating more relevant ideas ($M = 0.12, SD = 0.03$) than in the experimental condition ($M = 0.05, SD = 0.02$) (see Figure 6).

We then performed a within-conditions analysis by comparing the fluency for each storytelling stage (rising action, climax, and falling action) using a paired samples t-test. We found a statistically significant difference in fluency between the rising action and the climax stages, $t(9) = -8.88; p < 0.001, d = 2.32$. This suggests that children generated more relevant ideas during climax ($M = 0.30, SD = 0.10$) than during the rising action stage ($M = 0.09, SD = 0.08$). Specifically, a significant difference in the fluency related to the scenario was observed between the rising action and climax stages, $t(9) = -2.38, p = 0.04, d = 1.13$, suggesting more ideas related to the scenario during the climax ($M = 0.08, SD = 0.04$), than during the rising action ($M = 0.04, SD = 0.03$). A similar pattern was observed in the fluency related to story actions. Namely, a difference between the rate of ideas generated during the rising action ($M = 0.03, SD = 0.004$) and the climax stages ($M = 0.13, SD = 0.07$) was found, $t(9) = -5.51, p < 0.001, d = 1.75$. Results also showed a significant difference between the rate of fluency towards the character during rising action and climax stages, $t(9) = -5.00, p = 0.001, d = 2.21$; and during the falling action and the climax stages, $t(9) = -2.53, p = 0.03, d = 1.10$. Specifically, children generated a higher rate of ideas related to the character during climax ($M = 0.09, SD = 0.04$) than during the rising action ($M = 0.02, SD = 0.02$) and falling action ($M = 0.04, SD = 0.05$). These results showed that independently of the group, and during the climax stage, children generated more ideas for their stories related with the scenario, action, and characters (see Figure 7).

Regarding the elaboration of story actions, we observed a significant difference in the rate of ideas generated during climax and falling action stages, $t(9) = -2.69, p = 0.025, d = 1.00$, and between the rising action and climax stages, $t(9) = -3.65, p = 0.005$, favoring elaborations during climax. A similar pattern was found for the elaboration of the scenario, in which a statistically significant difference was found regarding elaborations about the environment where the characters are in the story space, deemed higher during the climax, $t(9) = -3.27, p = 0.010$. We also found a significant difference on elaboration regarding character dynamics during rising action and climax, $t(9) = -4.10, p = 0.003, d = 1.00$, favoring the climax stage. This suggests that children added/removed/hid characters in the peak of the action the story (climax), as some characters are present only in certain parts of the story and reappear later on. This result is also consistent with previous results that highlight that children's creativity peak during the storytelling is more emergent during the climax, which is the central moment of the story.

The last set of analyses performed concerns the originality of the ideas created regarding the characters, action, and scenario. To analyze the originality, two external coders used a Likert scale of 7 points in which originality was defined

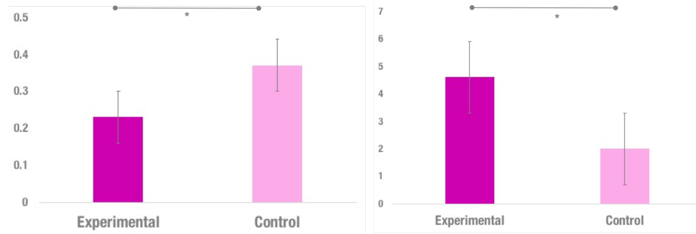

Figure 6: Results from the experimental study regarding the creative process of storytelling between conditions. On the left: Control condition showed higher fluency levels than the experimental condition, $p < 0.05$. On the right: Experimental condition showed a higher originality level of the creative process compared to control, $p < 0.05$.

[4] The coding scheme used to code the creative process can be accessed using the weblink: `https://osf.io/6cv93/?view_only=2c002947ad8046a0afa54b7a5ee4f5a9`.

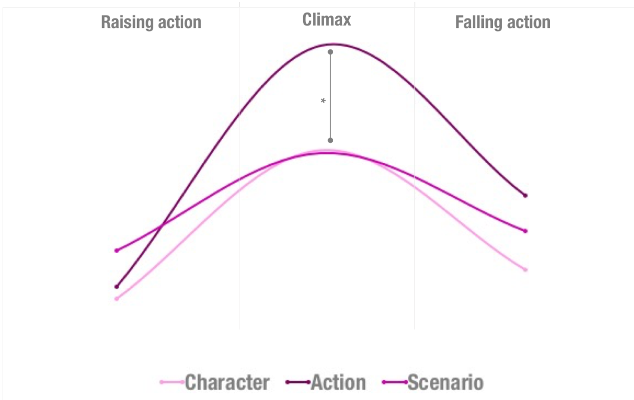

Figure 7: Within group analysis of the rate of ideas related to characters, actions, and scenarios across the stages of storytelling, namely rising action, climax, and falling action.

as the "uniqueness (rarity) of an idea in relation to a set of ideas" (Shamay-Tsoory et al., 2011) to code each idea generated during the creative process. For this, voice recordings were transcribed, and the coders coded each child's utterance in terms of originality. We observed 0.97 of agreement regarding the character category, 0.98 for the scenario, and 0.97 for action. Furthermore, we conducted t-tests to analyze the differences in the originality of ideas for each category and found significant differences in the originality of ideas only related to the character, $t(8) = 2.65, p = 0.03, d = 1.66$. These results suggest that more original ideas towards characters were generated in the experimental condition ($M = 4.60, SD = 2.10$) compared to control ($M = 2.00, SD = 0.71$) (see Figure 6).

Overall, the results show that the number of ideas generated (fluency) was superior in the control compared to the experimental condition. However, the originality of ideas regarding details about the characters was superior in the experimental condition. Therefore, the results partially support our hypothesis. There were also differences in the fluency and elaboration across different storytelling stages, in which more ideas and higher elaboration are present during the climax stage of the stories where peaks of action are prone to occur.

Creative Product

Given that CAT relies on a consensus regarding the perceived creativity of a given product, we started by calculating the inter-judge reliability of the ratings regarding the final stories created by children. Cronbach's coefficient alpha showed a moderate agreement between judges, $alpha = 0.68$ and $alpha = 0.70$, for the experimental and control conditions respectively (McHugh, 2012). Results in terms of the perceived creativity showed no statistically significant difference between conditions, $p > 0.05$, with mean ranks of 47.02 and 43.98, for the experimental and control conditions, respectively. Therefore, this result does not support our hypothesis.

Discussion

In this work, we evaluated the impact of a new creativity support tool, CUBUS, on children's creativity during a storytelling task. The effectiveness was evaluated in terms of the creative person, creative process, and creative product. Results concerning the creative process of children showed that children's fluency, i.e., number of ideas generated during the process of creating a story, is higher in the control condition; results also showed that the originality of the ideas produced about the characters during the creative process was higher in the experimental condition. This result translates the paradigm of quality versus quantity since children generate fewer ideas, but the ones generated are more original. This result seems to be in line with the idea that when ideas are generated under creative tasks or contexts, they are deemed more unique, even if they appear in less quantity (Derks and Hervas, 1988; Wierenga and Van Bruggen, 1998). Additionally, it makes sense that ideas about the characters in the experimental condition were more original since they were designed to provoke creativity in children through their emotionally expressive interactions. No other significant results were found.

Implications for Designing Tools for Creativity

Our study seems to support that when children play with tools or toys that convey and express emotion during storytelling, they engage in a more creative process. Specifically, this can inform toy designers to incorporate an emotional component to the new and interactive toys created for children. Additionally, this study shows that children can use minimalistic shapes, such as cubes, to create complex stories. This shows that simplicity in the design can provide engagement and interest in children towards a more abstract play in which the characters were non-stereotyped.

Conclusion

Our main contribution was the investigation of the role of emotionally expressive virtual agents in the social creativity of children during a playful activity. This activity revolved around a storytelling task in which children had to create a story using the emotionally expressive characters as their actors for the story. Due to the nature of the task, filled with creative potential by its open-ended and unrestricted creative process, children explored social creativity by engaging in collective creations of their stories.

Recommendations for future research

This study had several limitations that we would like to acknowledge. Regarding the lack of significant results concerning the effects of CUBUS in the creative person and the creative product, we attribute this to the small sample size in the evaluation study which consisted only of 20 children. Additionally, despite the study sessions being relatively long, children had a limited time to learn how to use the digital tool, which may have contributed to limiting the degree of creativity expression.

Although this study was conducted in school, it was performed in a private classroom which mainly replicates a lab setting due to its controlled environment. We would like to evaluate CUBUS in informal school settings with children and evaluate its effect on their creative levels. Regarding the lack of results in terms of the creative person, we would also like to acknowledge that we have used a figural test TCT-DP, which evaluated the creative potential of drawing products to show creative levels. Since the main task that children engaged in was verbal as they created a story, this might not have been the more adequate test to apply in this context. A measure that can evaluate verbal creativity could have been be more suitable taking into account the study design, as it can reveal important results, e.g., related to collaboration during a creative task (Kantosalo and Riihiaho, 2019).

Additionally, in terms of the creative product, future studies should contemplate a larger sample size in terms of children and external judges. Another variable can also be the variation in expertise across the judge. We would like to note that datasets and supplementary materials of the study are released online in Open Science Framework[5].

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References

Bakeman, R., and Quera, V. 2011. *Sequential analysis and observational methods for the behavioral sciences*. Cambridge University Press.

Baraka, K. 2016. Effective non-verbal communication for mobile robots using expressive lights. *Diss. Carnegie Mellon University Pittsburgh*.

Camurri, A.; Lagerlöf, I.; and Volpe, G. 2003. Recognizing emotion from dance movement: comparison of spectator recognition and automated techniques. *International journal of human-computer studies* 59(1-2):213–225.

Chan, S., and Yuen, M. 2014. Personal and environmental factors affecting teachers' creativity-fostering practices in hong kong. *Thinking Skills and Creativity* 12:69–77.

Ciechanowski, L.; Przegalinska, A.; Magnuski, M.; and Gloor, P. 2019. In the shades of the uncanny valley: An experimental study of human–chatbot interaction. *Future Generation Computer Systems* 92:539–548.

Csikszentmihalyi, M. 1996. *Flow and the psychology of discovery and invention*, volume 56. New York: Harper Collins.

De Dreu, C. K.; Baas, M.; and Nijstad, B. A. 2008. Hedonic tone and activation level in the mood-creativity link: toward a dual pathway to creativity model. *Journal of personality and social psychology* 94(5):739.

[5]Supplementary materials can be accessed using the following weblink: `https://osf.io/6cv93/?view_only=2c002947ad8046a0afa54b7a5ee4f5a9`.

Derks, P., and Hervas, D. 1988. Creativity in humor production: Quantity and quality in divergent thinking. *Bulletin of the Psychonomic Society* 26(1):37–39.

Di Blas, N.; Paolini, P.; and Sabiescu, A. 2010. Collective digital storytelling at school as a whole-class interaction. In *Proceedings of the 9th international Conference on interaction Design and Children*, 11–19. ACM.

Ekman, P.; Friesen, W. V.; and Ellsworth, P. 2013. *Emotion in the human face: Guidelines for research and an integration of findings*, volume 11. Elsevier.

Elkind, D. 2008. The power of play: Learning what comes naturally. *American Journal of Play* 1(1):1–6.

Fischer, G.; Giaccardi, E.; Eden, H.; Sugimoto, M.; and Ye, Y. 2005. Beyond binary choices: Integrating individual and social creativity. *International Journal of Human-Computer Studies* 63(4-5):482–512.

Fischer, G. 2007. Meta-design and social creativity: making all voices heard. In *IFIP Conference on Human-Computer Interaction*, 692–693. Springer.

Freytag, G. 1896. *Freytag's technique of the drama: an exposition of dramatic composition and art*. Scholarly Press.

Gilbert, A. N.; Fridlund, A. J.; and Lucchina, L. A. 2016. The color of emotion: A metric for implicit color associations. *Food Quality and Preference* 52:203–210.

Guilford, J. P. 1967. The nature of human intelligence.

Hall, E. T. 1966. The hidden dimension. 1966.

Heider, F., and Simmel, M. 1944. An experimental study of apparent behavior. *The American journal of psychology* 57(2):243–259.

Hemphill, M. 1996. A note on adults' color–emotion associations. *The Journal of genetic psychology* 157(3):275–280.

Hennessey, B. A.; Amabile, T. M.; and Mueller, J. S. 1999. Consensual assessment. *Encyclopedia of creativity* 1:346–359.

Hornecker, E., and Stifter, M. 2006. Learning from interactive museum installations about interaction design for public settings. In *Proceedings of the 18th Australia conference on computer-human interaction: design: activities, Artefacts and Environments*, 135–142.

Humphrey, T., and Gutwill, J. P. 2017. *Fostering active prolonged engagement: The art of creating APE exhibits*. Routledge.

Hutton, E., and Sundar, S. S. 2010. Can video games enhance creativity? effects of emotion generated by dance dance revolution. *Creativity Research Journal* 22(3):294–303.

Jack, R. E.; Garrod, O. G.; and Schyns, P. G. 2014. Dynamic facial expressions of emotion transmit an evolving hierarchy of signals over time. *Current biology* 24(2):187–192.

Jellen, H. G., and Urban, K. K. 1986. The tct-dp (test for creative thinking-drawing production): An instrument that can be applied to most age and ability groups. *Creative Child & Adult Quarterly*.

Jellen, H. G., and Urban, K. K. 1989. Assessing creative potential world-wide: The first cross-cultural application of the test for creative thinking—drawing production (tct-dp). *Gifted Education International* 6(2):78–86.

Kampylis, P. G., and Valtanen, J. 2010. Redefining creativity—analyzing definitions, collocations, and consequences. *The Journal of Creative Behavior* 44(3):191–214.

Kantosalo, A., and Riihiaho, S. 2019. Experience evaluations for human–computer co-creative processes–planning and conducting an evaluation in practice. *Connection Science* 31(1):60–81.

Keltner, D., and Ekman, P. 2015. The science of 'inside out. *New York Times* 3.

Long, D.; Gupta, S.; Anderson, J. B.; and Magerko, B. 2017. The shape of story: A semiotic artistic visualization of a communal storytelling experience. In *Thirteenth Artificial Intelligence and Interactive Digital Entertainment Conference*.

McHugh, M. L. 2012. Interrater reliability: the kappa statistic. *Biochemia medica: Biochemia medica* 22(3):276–282.

Nijdam, N. A. 2009. Mapping emotion to color. *Book Mapping emotion to color* 2–9.

Nogueira, S. I.; Almeida, L. S.; and Lima, T. S. 2017. Two tracks of thought: A structural model of the test for creative thinking-drawing production (tct-dp). *Creativity Research Journal* 29(2):206–211.

Plucker, J. A.; Beghetto, R. A.; and Dow, G. T. 2004. Why isn't creativity more important to educational psychologists? potentials, pitfalls, and future directions in creativity research. *Educational psychologist* 39(2):83–96.

Runco, M. A.; Acar, S.; and Cayirdag, N. 2017. A closer look at the creativity gap and why students are less creative at school than outside of school. *Thinking Skills and Creativity* 24:242–249.

Salonius-Pasternak, D. E., and Gelfond, H. S. 2005. The next level of research on electronic play: Potential benefits and contextual influences for children and adolescents. *Human Technology: An Interdisciplinary Journal on Humans in ICT Environments*.

Sawyer, R. K., and DeZutter, S. 2009. Distributed creativity: How collective creations emerge from collaboration. *Psychology of aesthetics, creativity, and the arts* 3(2):81.

Shamay-Tsoory, S.; Adler, N.; Aharon-Peretz, J.; Perry, D.; and Mayseless, N. 2011. The origins of originality: the neural bases of creative thinking and originality. *Neuropsychologia* 49(2):178–185.

Shuster, M. M.; Mikels, J. A.; and Camras, L. A. 2017. Adult age differences in the interpretation of surprised facial expressions. *Emotion* 17(2):191.

Snibbe, S. S., and Raffle, H. S. 2009. Social immersive media: pursuing best practices for multi-user interactive camera/projector exhibits. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 1447–1456.

St-Louis, A. C., and Vallerand, R. J. 2015. A successful creative process: The role of passion and emotions. *Creativity Research Journal* 27(2):175–187.

Sternberg, R. J., and Sternberg, R. J. 1999. *Handbook of creativity*. Cambridge University Press.

Sutton, T. M., and Altarriba, J. 2016. Color associations to emotion and emotion-laden words: A collection of norms for stimulus construction and selection. *Behavior research methods* 48(2):686–728.

Terada, K.; Yamauchi, A.; and Ito, A. 2012. Artificial emotion expression for a robot by dynamic color change. In *2012 IEEE RO-MAN: The 21st IEEE International Symposium on Robot and Human Interactive Communication*, 314–321. IEEE.

Terwogt, M. M., and Hoeksma, J. B. 1995. Colors and emotions: Preferences and combinations. *The Journal of general psychology* 122(1):5–17.

Thomas, F.; Johnston, O.; and Thomas, F. 1995. *The illusion of life: Disney animation*. Hyperion New York.

Tinwell, A.; Grimshaw, M.; Nabi, D. A.; and Williams, A. 2011. Facial expression of emotion and perception of the uncanny valley in virtual characters. *Computers in Human Behavior* 27(2):741–749.

Tottenham, N.; Phuong, J.; Flannery, J.; Gabard-Durnam, L.; and Goff, B. 2013. A negativity bias for ambiguous facial-expression valence during childhood: Converging evidence from behavior and facial corrugator muscle responses. *Emotion* 13(1):92.

Urban, K. K. 2005. Assessing creativity: The test for creative thinking-drawing production (tct-dp). *International Education Journal* 6(2):272–280.

Wallbott, H. G. 1998. Bodily expression of emotion. *European journal of social psychology* 28(6):879–896.

Ware, C. 2012. *Information visualization: perception for design*. Elsevier.

Wierenga, B., and Van Bruggen, G. H. 1998. The dependent variable in research into the effects of creativity support systems: Quality and quantity of ideas. *MIS quarterly* 81–87.

Winer, B. J. 1962. Statistical principles in experimental design.