Synthetic Characters for Creative Child-Computer Interaction

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Abstract

Creativity is known as an ability that can be developed and improved. Since creative abilities are desired in most nowadays societies, it becomes important to develop activities that stimulate creativity at a very young age. It seems, however, there is a lack of tools to support creative activities for children. We present *Cubus*, a tool that uses autonomous synthetic characters to stimulate idea generation in groups of children during a storytelling activity. With Cubus, children can invent a story and use the stop-motion technique to create a movie depicting it. This work yielded a useful methodology that we consider can aid the design of tools which assist users in their task. This methodology consists in an iterative development where several user studies are carried out to inform and validate design choices during a tool's different development stages. Additionally, a methodology to evaluate the different aspects of creativity is also presented and implemented during our creativity evaluation with Cubus. To evaluate how Cubus supports creativity, we investigated the number of ideas generated by groups of children during their creative process of creating and recording a story and the creativity of the product this process originated, a stop-motion movie. Results showed that the embodied synthetic characters with autonomous behavior of Cubus contributed to the generation of more ideas in children, a key aspect of creativity. Regarding the creative product, results suggest that Cubus agents' autonomous behaviors were unable to influence children's creative products, the stop-motion movies.

Keywords: autonomous virtual agents, child-agent interaction, creativity support tool, group creativity with children, creative storytelling

Introduction

The role of creativity is paramount in modern societies. Creativity contributes in a major way to both our professional and personal growth. It is therefore important to encourage the growth of this ability from a very young age in our schools (Mellou 1996). Although many schools already feature storytelling activities which help promote the children's creative thinking (Di Blas, Paolini, and Sabiescu 2012), these activities are cumbersome for teachers to prepare and manage, with scarce tools existing to support these activities (Chan and Yuen 2014).

With this work, we propose to enhance children's creativity, by focusing on the stimulation of idea generation during their creative process. As identified by Torrance (1979), idea generation (also denominated by *fluency*) is one of the primary aspects of the creative process. Our system, *Cubus*, emerges as a virtual environment that allows groups of children to engage in creative storytelling while interacting with the autonomous synthetic characters that are part of Cubus. Three dimensions were taken into account for the evaluation of how Cubus enhances creativity: *creative process*, *creative product*, and impact on the participants' *creative abilities*. In this work, we focused on the analysis of the *creative process* and the *creative product*. Our evaluation study was planned to verify two hypotheses, that the addition of the synthetic characters' *autonomous behaviors* would increase idea generation in groups of children during the creative process of storytelling and that this richer creative process would cause the children's creative product, the stop-motion movie, to be perceived as being more creative.

The remainder of this document is organized as follows: (1) we start by providing a *theoretical overview* that framed and inspired Cubus; (2) describe the *technical development* of the system; (3) present *user studies* that were conducted to inform the development and the final evaluation of Cubus; (4) and conclude by presenting *final remarks and main contributions*.

Creativity

Creativity is a concept that has no consensual definition, but there is an overall agreement that creativity can be defined as the "interaction among aptitude, process, and environment by which an individual or group produces a perceptible product that is both novel and useful as defined within a social context" (Plucker, Beghetto, and Dow 2004). This work is framed within the research area of computational creativity. Before starting the development of the Cubus system it was crucial to study and understand the different ways that tend to contribute to a creative process. Torrance (1979), cites four fundamental creative abilities in the creative process: fluency, flexibility, originality and elaboration. With this work, we focus only on stimulating *fluency*, the number of ideas generated during a creative process. Not only we want to stimulate fluency during the creative process, as we are also interested in improving this creative ability within a group. In this context, creativity deviates from emerging from an *individual* creative process, to become an ability that is stimulated in a *distributed way within a group* (Sawyer and DeZutter 2009). During the unscripted collaborative efforts that emerge during the creative process, improvisation is key as it involves creating different ideas as well as adapting to concepts introduced by others and building upon them (Sowden et al. 2015). In the case of our system, we used Cubus to stimulate fluency in groups of children during storytelling.

Creativity Support Tools

Our work contributes toward the enhancement of creativity with the aid of computers, defined as the field of Creativity Support Tools (CSTs) (Shneiderman 2007). We took inspiration from works such as *Dr. Inventor* (Donoghue et al. 2014) and a work that uses a physical agent to aid children in creative storytelling (Ryokai and Lee 2009). As *motivation* is one of the foundations for a successful creative experience (Amabile and Hennessey 1992), we rely on agents to motivate users in their task (Kahn et al. 2016). Additionally, it seems that the use of a synthetic character did not hinder communication and was able to enhance discussion in a collaborative task with pairs of children (Ryokai, Vaucelle, and Cassell 2003), reinforcing our motivation to include synthetic characters in our scenario.

Human-Agent Interaction

Cubus system features synthetic characters and their design inspiration includes previous work in the area of Human-Agent Interaction (HAI). Given that our characters are non-humanoid, we faced several challenges in designing their emotional expressive behaviors. To address emotional expression when designing characters with a restrictive appearance, we followed an extensive survey carried out by Bethel and Murphy (2008). In this survey different means of expression are suggested, such as movement (Wallbott 1998; Argyle 1973), color (Argyle 1973; Terada, Yamauchi, and Ito 2012), sound and proxemics (Friedman, Steed, and Slater 2007). We incorporated several of these means and guidelines while designing how our synthetic characters should interact with the user and with each other to increase their chances of expressing themselves successfully.

Cubus System

Our work features a virtual environment which contains a small set of world building tools and synthetic characters (Figure 1). The system was tailored to fit the target audience of children between the ages of 7 and 9 years old. Our main concern during the development of Cubus was to keep it accessible for children and open-ended to leave space for creation, allowing the creative storytelling process to unfold. Cubus can be divided into two primary components:

- **Synthetic characters:** Our characters will be featured in the children's story as their *actors*;
- **Virtual environment:** The environment is responsible for supporting the world building features and recording the story that children create.

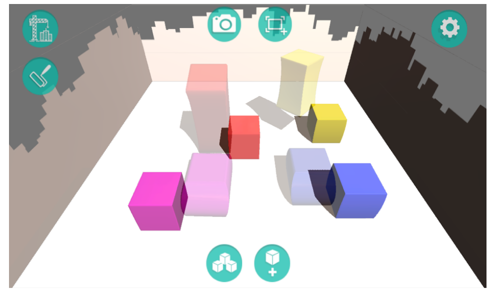

Figure 1: Virtual environment.

The development of this work was carried out with the Unity™ game engine (version 5.3.5f1) and our testing environment consists in a Samsung™ Galaxy Tab Pro 10.1 tablet through the use of its touch interface (Android™ 5.1.1).

Synthetic Characters

The *synthetic characters* were designed to be non-humanoid and rely on the emergent interaction between them for emotional expression. Using this interaction among the characters toward stimulating creativity is the most innovative part of this work. For brevity, "synthetic characters" will be addressed as "agents" for the remainder of this document.

Agents' Implementation: Each agent corresponds to one of five specific emotions (anger, happiness, fear, sadness and disgust), displaying behaviors autonomously that are consistent with that emotion (Wallbott 1998). There is no limit to how many agents of a given emotion can be present in our environment at a given time. To add more depth to the agents' emotional displays, two types of behaviors were created for each emotion: a *standard behavior* and an *intense behavior*, the latter being perceived as a stronger display of the given emotion.

Additionally, each agent has two drives: one that triggers the *standard behavior* and another that triggers the *intense behavior*. These drives vary between 0 and 90. The **standard drive** starts at a random value between 0 and 35 and increases with the passing of time (1-second intervals). When this drive reaches 90, it triggers the standard behavior and resets its value to 0. Additionally, this timed increase "step" is affected by a multiplier, within the range of 1 to 1.5 for the standard drive and 1 to 1.3 for the intense drive. These multipliers are set randomly within these ranges at the moment of the agent's creation. Both elements of randomness introduce diversity to the different agents' behaviors, reducing their predictability and making their interaction appear more natural. The same drive also increases when other agents display any behavior within a certain radius of the agent. The **intense drive** starts at 0 and only increases with time until 65, after this point only increases when stimuli from other agents' behaviors (which share the same emotion) are received. When this drive reaches 90 the corresponding behavior is triggered and both drives are reset. It should be noted that while a behavior is occurring, no stimuli are received from other agents.

These agents interact with each other by broadcasting stimuli to the surrounding agents when they display a behavior. The intensity of these stimuli differs taking into account the distance to other agents (closer agents provide stronger stimuli). These distances are fixed for every agent and are divided into three intervals as evidenced in Figure 2. The contributions from the stimuli vary from 25 to 45 when contributing toward the standard drive and between 35 and 60 for the intense drive. With the combination of these mechanisms, we empowered children to create unique scenes in their story that emerged from the actors they chose, as well as how they placed them.

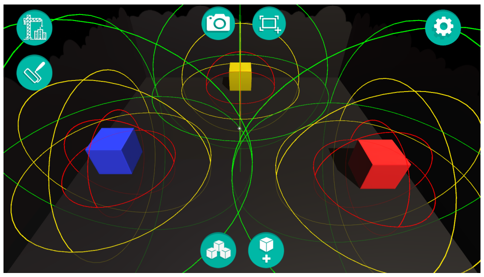

Figure 2: Proxemic distances that weigh agents' interactions.

Appearance: We have chosen a neutral appearance for the agents' design to provide the possibility for children to project any desired character. To this end, the geometric shape of a *cube* was selected, inspired by LEGO™ bricks. Since emotions seem to enhance creativity in video games (Hutton and Sundar 2010), it was important to establish which emotions we were attempting to represent. We considered Ekman's (1972) model of six emotions to be appropriate for our context, omitting surprise emotion given that there is no consensus regarding its inclusion as an emotion (Jack, Garrod, and Schyns 2014).

Expression: We focused on two primary means of communication for the agents: color and body movements/posturing. To combine these features appropriately and make them be perceived as natural during the agents' animations, we studied Disney™'s twelve principles of animation (Thomas, Johnston, and Thomas 1995). These principles address the human need for more pronounced cues in order to correctly perceive actions or affective displays by virtual agents. The most relevant principles in our design were: squash and stretch, anticipation, follow-through, and staging.

Color: In order to create an identity for our emotions, some emotion-color associations were selected, the inspiration for these was drawn from Disney™'s movie *Inside Out*. This movie's target audience were children and the designers behind it have a vast experience in representing and portraying emotion. Additionally, Ekman was one of the scientific consultants for this movie and the emotions present in the movie feature one predominant color. As such, we considered that the unique colors associated with each emotion would create distinguishable agents.

In an effort to direct the users' attention to the agents' behaviors we also added a blinking effect triggered in the beginning of the agents' behaviors. This blinking remains within the hue of each agent's base color and depending on the valence of its emotion, the blinking varies, being brighter when the valence is positive (*e.g.*, happiness) or darker for a negative valence (*e.g.*, anger). This blinking effect also varies according to the arousal of each emotion, *e.g.*, happy and angry emotions have a high arousal and therefore, the blinking will have a high frequency. By comparison, when sadness is being displayed this blinking will be slower. The frequencies used for this effect were tuned to ensure they were distinguishable and represented the different arousal levels.

Body Movement and Posture: In addition to detailed animation principles, we explored character deformation in our animations to create simple but organic movements for the agents. This step toward deformable characters enabled a more appropriate representation of simple actions (*i.e.*, jumps, nods, squats, etc). Some of the aforementioned animation principles, such as squash and stretch or follow-through, helped convey the physical impact actions have on a character's body as seen in Figure 3. To convey our particular set of emotions through animation, we considered Wallbott's (1998) work, which summarizes some of Darwin's observations regarding movement and posture in emotional expression. These observations provided insight to create the desired set of emotions for our agents, as well as for their arousal state. For example, stretching the body and mimicking an inflated chest while leaning forward conveys anger, as opposed to squashing and tilting down while staying motionless which conveys sadness. When combined and properly timed, these cues produced the final version of our animations for the agent's expression. In an effort to increase our agents' expressiveness, two animations were designed for each emotion. Each agent exhibits two different intensity levels for every emotion: standard and intense. This allows the agent to express the heightened emotional intensity of interacting with other agents that feature the same emotion.

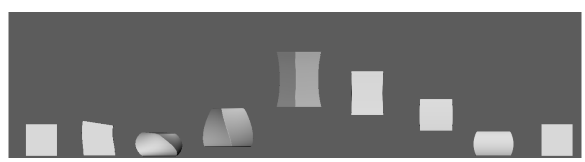

Figure 3: Happiness emotion's spinning jump (key frames).

Interactive Virtual Environment

The virtual environment sustains both the interaction between children and our agents, as well as the children's storytelling process (Figure 1). This environment allows the recording of the children's story, managing and directing the agents and customizing virtual scenarios. For the design of the system, we followed a modular approach with four major components: screen recorder, world building tool set, agents, and user interface (UI) manager. The screen recorder module is responsible for the capture of 3D objects in the scene, while excluding any screen overlays or UI elements. The world building tools control and carry out children's inputs when managing their scenes. This ranges from changing the scenario to creating and deleting agents. A UI manager module serves as the interface between the children's inputs and both the agents and the tool set.

Stop-motion: To allow the recording of the stop-motion story, children can perform screen captures when creating scenes to feature in their movie. These screen captures omit the application's UI elements and record only the actors and scenario. The images resulting from the screen captures are stored within the device and, at a later stage, imported into an application that supports the creation of a stop-motion movie. Two features were added to help children understand how to use the system: an effect mimicking a camera flash each time a screen capture is performed, helping confirm the action; and an overlay of the children's previous screen capture with small opacity that covered the entire screen (visible in Figure 1). This last feature was useful, as some children showed difficulties recalling their last recorded moment in the story, *e.g.*, when they changed the story scene. It is also possible to create intertitle screens (as seen in silent movies). These allow children to record a screen with a written message, enabling them to explore and explain more drastic changes within their story.

World: The virtual environment gives children enough degrees of customization to personalize the story. Several scenarios are available in our environment, these are very distinguishable from each other and allow for different uses. Their topologies are quite different (*e.g.*, curvilinear, rectilinear or with sharp angles), while still being very much open to interpretation. To point out an example, our "spiky" scenario was seen as pine trees, mountains or traps by children. To provide children more creative freedom, a color selection screen was added, enabling children to select a color for the scenario and another for the skybox that envelops it.

Interacting with the actors: The building tools allow children to create and manage their actors. To this end, children are able to select which type of agent (or actor) they wish to feature in their story. Additionally, children can access a list of all their actors, through which they can hide, reveal and delete actors. The ability to toggle an actor's visibility is useful for actors that are not in every scene of the story, allowing children the creative freedom to experiment with more complex storytelling narratives. To control the actors, children can perform dragging (press on the agent with their finger and drag it from one point to another) and rotation movements (press on the agent with one finger to select it and use another finger to slide up or down, to rotate forward or backward) of their actors. These movements allow children to represent characters walking around or facing an important object or character in any given scene.

User studies with Cubus

This section presents three studies performed in the scope of Cubus' development and evaluation. Henceforth, we present (1) a *co-design study* with children, whose main goal was to inform the development of Cubus, (2) a *usability test* to study the prototype version of Cubus with children, (3 and 4) and the *final evaluation of Cubus* an experimental study in a school. The analysis for this last study was split between the analysis of (3) the creative process and (4) the creative product. For all studies and prior to children's participation, parents signed an informed consent which stated their willingness in letting their child perform the study, and each child verbally assented to participate. Children that participate in each study are different subjects and belong to different schools.

(1) Co-design

In the words of Melonio and Gennari (2012), "co-design, is an approach to design attempting to actively involve all stakeholders in the design process in order to help ensure the product designed meets their needs and is usable" . Therefore, the main goal of the co-design study was to involve children in creating design solutions as well as guide the design decisions related with the development of the agents for the Cubus system.

Sample: 52 children with ages between 6-10 years old participated in this study (M = 7.93, SD = 1.32, 25 female). Each session was composed of groups of 3-4 mixed gender children (grouped by their school teacher) in a total of 11 groups. Thus, 11 sessions were performed in a classroom setting and each session lasted about one hour.

Materials: For this study, paper prototypes in the form of cubes were used. They were made using an origami technique and could be one of three different sizes: small, medium and large (see Figure 4 for a small size origami cube). Each cube was built to integrate a crayon inside so that children would see the result of their animations for each cube in large sheets of paper used as playgrounds.

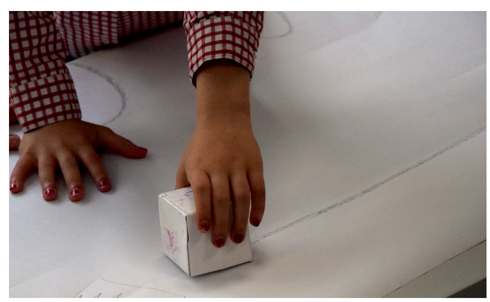

Figure 4: Children interacting with origami cubes that served as prototypes for the development of Cubus' agents during the co-design study.

Procedure: In order to conduct a successful co-design session with groups of children, we applied the CHECk tool (Van Mechelen et al. 2014) to best explain to children their role as design partners in a co-design session as well as to set expectations. After this, children were invited to create movements for the paper cubes taking into account different personality traits for the cubes (*e.g.*, they could develop animation movements for a cube that was said to be an introvert), and were also asked to create a cube that they liked (freestyle cube). According to the instruction provided, children chose the cube size that they perceived best fitted the personality trait and performed several animations on the paper sheet. Children were asked to develop movements inspired in five personality traits (Goldberg 1990) and a freestyle movement.

Results: This study showed that children at a young age were able to animate a cube as if it was a character by giving it different movements and colors according to different personality traits (*e.g*., an extrovert cube would be animated with curvilinear movements with high amplitude and fast speed, whereas an introvert cube would be animated with a straight, slow and self-contained movement). Situations existed in which children created short-stories for their cubes according to the personality trait they were working on, therefore validating the storytelling approach. This has showed that using a cube did not limit children's play and imagination, serving well the purposes of storytelling for Cubus. When asked to create their freestyle cube, children were able to create a wide range of different characters, from animals such as lions, to the Spider-man, or a cube with the super-power of firing laser beams. The ability to conceive a wide range of characters for their cubes provided evidence that a minimalist toy such as a cube, can serve to project many and different ideas successfully providing a fit design for the purposes of our main study.

(2) Usability Testing

Usability testing enables the identification of some key interaction problems in user interfaces (Resnick et al. 1998). While developing emerging technologies for children, involving them as users, testers, informants, or design partners becomes an essential part of the process (Druin 1999). In this study we present the usability testing with children of a prototype of Cubus.

Sample: 7 children with ages between 7 and 9 years old participated in the usability study (M = 7.86, SD = 0.90, 3 female). In order to test the full usability of Cubus with children we performed both individual and group sessions in a classroom setting. Thus, we conducted a total of 4 sessions: 3 group sessions with a pair of children in each, and 1 individual session. Each session lasted between one hour to one hour and a half.

Materials: The main goal of this study was to test a Cubus-prototype in which the agents had no autonomous behaviors yet, to detect major usability problems with the application during the entire process of storytelling creation. We used the Cubus-prototype and two different stop-motion applications to generate children's movies, in order to test which was more adequate.

Procedure: We relied on specific usability evaluation methods to elicit information from children (Van Kesteren et al. 2003). Thus, we used the *active intervention technique* to ask questions to children about what they have done or will do; the researchers motivated children to perform the task cooperatively, discovering together the potentialities and/or limitations of Cubus by using the *co-discovery technique*; and the *retrospection technique* was used toward the end of the session when reviewing some situations that stood out. Each usability session followed the stages described below:

1. *Getting to know each other.* Children would enter the classroom and were invited by a researcher to sit at a desk where the activity would take place. In order to break the ice, the two researchers (one researcher was responsible to organize the task while the other took notes about the session) introduced themselves and encouraged children to do the same. Researchers initiated a dialogue with children about their favorite activities and their knowledge about using a tablet/iPad. Once children were feeling comfortable, the researchers moved to the next stage;
2. *Initial instructions, before actually starting.* During this stage, researchers introduced the activity to children, explaining they would create a stop-motion movie. During this phase it was explained to children what a stop-motion movie was and the techniques on how to create it;
3. *Interacting with Cubus-prototype.* Children were invited to start creating a story using Cubus. To provide structure for the sessions, researchers provided the theme for their story, instructing children that their story should start with someone dreaming and should end with someone waking up. Following this, children were prompted to initiate the storytelling activity by thinking about a place, an actor, and an action for their story using Cubus as their testbed. They were also encouraged to take screen captures of all the scenes they wanted to include in their stop-motion movie. When their movie was finalized, they were instructed to be the narrators of their story.

Identified problems and corresponding solutions: During this study, Cubus-prototype included features that were prone to be tested with children to understand their design success. For example, each agent of Cubus had a red button that children could click on if they wanted it to record ideas for their story. Therefore, the usability testing provided important insights on existing problems with the Cubus-prototype version that we were able to identify by analyzing the behavior of children during the usability sessions. Some of the problems and solutions are depicted on Table 1.

A take-home message from the usability testing study was that children invest their time in learning how to use functionalities they felt were interesting or useful for their storytelling process, *only if these functionalities have a direct impact on the final product*. Any features that did not connect directly to the end result were cast aside and rarely or never used.

(3) Evaluation study - Creative process

An experimental study was performed in a school setting to investigate if Cubus can stimulate fluency of ideas in children while performing a storytelling task. To study this, we have analyzed the fluency of ideas (number of ideas generated) by comparing two experimental conditions:

- **Autonomous condition:** in which children interacted with the autonomous version of the agents;

Table 1: Examples of problems found during the usability testing of Cubus-prototype and corresponding applied solutions.

	Problems found	Applied solutions
Agents	Children avoided using a special record-button integrated in the design of the agent and whose purpose was to store their verbally expressed ideas when they realized that the stored ideas were automatically erased for the final movie.	The record-button was removed from the agent's design as it had no direct impact on the final movie.
	The size of the agents was perceived to be too small.	The size of all cubes was enlarged.
Virtual enviro.	Location of some menus was not obvious for children, along with the scrolling options and clicking dynamics.	The virtual environment was generally improved.
Technical features	Changes in the camera's perspective led to confusion in the final movie as children were not able to integrate the perspective change when narrating the story.	Changed to a fixed camera perspective to simplify the mapping between the actions on Cubus and the effects on the final movie.

- **Non autonomous condition:** in which children interacted with the same agents whose behavior they control directly. Additionally, children can select one of three sizes for each agent (small, medium or large).

We hypothesize that children will have higher fluency in the autonomous condition when compared to the non autonomous one. During this study, children will produce a movie, their creative product, which will be subjected to an analysis as well. To present our analysis of both aspects of creativity in a clearer way, the creative product will be covered separately in the following section since it required several additional steps, such as assembling a panel of judges and the creation of a questionnaire to evaluate children's movies. While discussing these two aspects we will detail the steps taken during their analysis and how we approached certain issues. These sections will also present and discuss the results obtained from our analysis.

Sample: 20 children participated in the evaluation of Cubus, with ages ranging from 7-9 years old ($M = 8.10$, $SD = 0.72$, 14 female). Our sample was split evenly between conditions with 10 children featured in each condition. Children performed the task in pairs, therefore, each session consisted of two children interacting with Cubus with a total number of 10 sessions. The pairs of children were organized by their school teacher who selected children that were friends and that played well together. Each session lasted approximately one hour and was lead by two researchers: one researcher with a computer science background and with knowledge on the specifics of Cubus, and a psychologist.

Procedure: Pairs of children entered the designated classroom in which the study would be performed. The flow of the study can be divided into four stages:

1. *Saying hello.* The initial phase consisted of the presentation of each child and of each researcher in order to get to know each other. During this phase, the leading researcher explained that the goal of the activity was to create a stop-motion movie using Cubus. As most children were not familiarized with stop-motion animation, this notion was explained to them. To do this, the researcher used Cubus to provide a basic example of an agent walking from one side to the other in the virtual environment while performing screen captures of each frame, and then showed the end product of the movie. As children got engaged with the notion of stop-motion, they were motivated to try it by themselves using Cubus. This enabled the explanation of the basic features of Cubus and at the end of this stage, children were familiar with the system and ready to start their own movie;
2. *Hands on Cubus.* The researcher explained to the pair of children that their movie had to follow a theme (*i.e.*, their story needed to start with someone dreaming and to end with someone waking up). For all sessions, Cubus was set to the following mode: a clear Cubus world with a white color as a metaphor for a white paper sheet. Children started to create their story collaboratively (actors, actions, scenarios, and plot) (see Figure 5) and the role of the researchers was to support their questions regarding any dynamics with respect to using Cubus, or to keep the storytelling flow and rhythm going by asking questions such as, "what is your actor going to do now?" or "what happens next?". Children had no knowledge about the behavior and color associations of the agents' emotions. This stage continued until the pair of children finished creating their story using the stop-motion technique;
3. *Narration.* After having completed their stop-motion movie, children performed the voice narration for their story. The voice narration of the movie consisted of children speaking (either as narrators, actors, or even making a soundtrack) to a voice recorder while watching their movie play. As children did not have a written script, they were able to train the narration several times until they felt comfortable. It is important to note that although each narration was grounded on the main story plot defined by children, each narration was different and tied with the improvisation between children about what was happening in the movie. This stage ended when the stop-motion movie had a narration;
4. *Saying goodbye.* The last stage of this study consisted of watching the movie with the children and congratulating

them on their accomplishment.

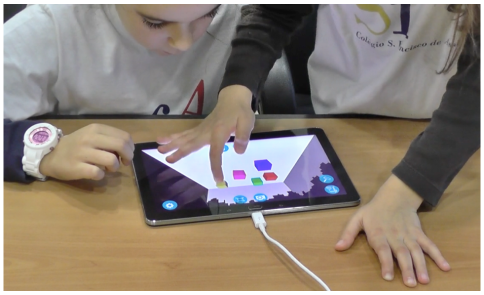

Figure 5: Children interacting with Cubus system.

Data analysis: To study if the presence of autonomous agents during a storytelling task increased the fluency of ideas (*i.e.*, number of ideas generated) by children, we performed behavior video analysis of the recorded sessions (10 sessions in total). The video analysis was focused only on the *Hands on Cubus* phase, described in the Procedure. Therefore, the behavior analysis concerned only the *process* of the stop-motion movie creation. The main goal of the behavioral analysis was to analyze the *fluency of ideas of children during the creative process of creating the stop-motion movie while interacting with Cubus in each experimental condition*. To this end, a coding scheme for fluency of ideas was generated in order to perform the behavioral analysis, and is described below:

- **Idea** - The first step was to define what an actual *idea* was in the context of the storytelling activity, to differentiate it from the rest of the interaction. Therefore, *an idea was defined as a verbal interaction between children that has the potential to add a detail to the story that is being created. Ideas can appear in duplicate and are still considered ideas even if children decide not to use them in the final story.* In this context, an idea can be a verbal detail related to the actors, actions, scenario, or other, if related to the story that is being created. An interaction that concerns technical details of how to manage Cubus was not considered an idea, *e.g.*, when a participant asked "how can I add another actor?".

The next step was to differentiate between the *types of ideas* that were generated. This type of coding is dependent on the content of the ideas and can be divided into two different types of ideas, described below:

- **Idea-agents** - An idea that derives from the interaction with the agents needs to be *related with the agents' characteristics, such as color, size, and/or behavior*. For example, if a participant states that an agent "became bigger", it does not count as an idea. Whereas if a participant says that "[the agent] has become bigger to scare someone", it is considered an idea derived from the interaction with the agent;
- **Idea-children** - This type of idea encompasses *any idea that derives from the imagination of the participants and that connects with the story* (and that is not related to the agents). Examples can be the choice of a shape for a given scenario (*e.g.*, a "spikier" world) or the colors of the scenario.

Video analysis was performed using ELAN software (Wittenburg et al. 2006) and conducted by two researchers. One researcher coded 100% of the data and the second researcher coded 40%. Since one of the variables was a constant, the Percent Agreement Method (McHugh 2012) was used to calculate the inter-judge agreement for the coding of "Ideas", revealing an agreement of 87%. Cohen's Kappa (Cohen 1968) was used to calculate the inter-judge agreement for "Ideas-agents" and "Ideas-children", revealing an agreement of $K = 0.947$ and $K = 0.932$, respectively.

Results: The results of this study include the analysis of the number of *ideas-agents* (ideas generated by children resulting from the interaction with the agents) and *ideas-children* (ideas generated by children connected only with the story and not dependent on the interaction with the agents). Given the small size of the sample, non-parametric tests were used to analyze the data. Therefore, to analyze the **ideas-agents**, a Mann-Whitney U test was used revealing that the number of ideas that emerged from the interaction between the participants and the agents differed statistically across conditions, $U = 15$, $p = 0.007$, $r = 0.60$. By analyzing the mean ranks it can be seen that the number of ideas generated was higher when participants interacted with autonomous agents (*Mean rank* = 14.00) compared to the non autonomous agents (*Mean rank* = 7.00) (see Figure 6). Additionally, we have calculated the difference for the number of **ideas-children** between conditions. A Mann-Whitney U test showed that the number of ideas generated by children that are connected with the story and that were not dependent upon the interaction with the agents does not statistically differ across conditions, $U = 38$, $p = 0.364$, $r = 0.20$. Despite the non-significant result, the number of ideas generated was higher in the autonomous condition (*Mean rank* = 11.70) in comparison with the non autonomous condition (*Mean rank* = 9.30). Overall, results suggest that the number of ideas generated by participants differs statistically between conditions when looking at the number of ideas generated by children when interacting with the agents. This result corroborates our study hypothesis, showing that children are able to generate more ideas when interacting with autonomous agents compared to non autonomous ones.

(4) Evaluation study - Creative product

This section details the process through which we analyzed the stop-motion movies children created during our evaluation study (the process through which these movies were created is covered in the previous section). Regarding the creative product, we hypothesize that movies created with Cubus agents' autonomous behaviors will be perceived, by a panel of independent judges, as being more creative. To conduct the creative product's evaluation, the Consensual Assessment Technique (CAT) was applied (Hennessey, Amabile, and Mueller 2011). This technique relies in using a panel of independent judges to analyze the creative product, in our case, the stop-motion movies children created.

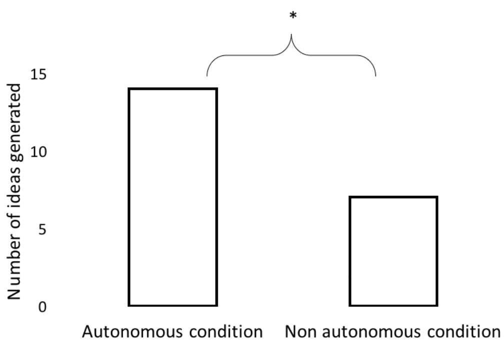

Figure 6: Mean ranks of the ideas generated (fluency) by children, resulting from the interaction with the agents. (*) denotes $p<0.01$.

Sample: The panel was composed of nine judges, aged between 19-54 years old ($M = 42.0$, $SD = 10.1$, 7 male). Our judges were specialized within the area of cinema, ranging from directors and animators to college teachers.

Evaluation technique: When applying the CAT, some requirements should be met for a fair and reliable evaluation process (Hennessey, Amabile, and Mueller 2011). In particular: (1) the panel of judges should have similar expertise — in our case, the panel had similar expertise in the area of cinema; (2) judges should rate the movies independently and share no information during the process; (3) to avoid an unfair evaluation, by comparing the children's movies with an external standard, all movies should be evaluated by comparison only to each other, and; (4) when presenting the movies to the judges, their order should be randomized, thus ensuring that no order effects occur. To properly apply CAT, we followed these requirements while assembling our expert panel and guiding their evaluation of the creative products.

Procedure: This evaluation was done through an online questionnaire containing all the 10 movies (from both conditions) children created accompanied by a continuous scale which allowed rating them. The procedure started by contacting the experts which composed our evaluation panel and ask for their voluntary cooperation in evaluating the children's movies. This contact was carried out through an email in which the purpose and the conditions of our study were summarized and disclosed, along with the expected timeframe of 30 minutes for answering the questionnaire. This email also contained the link which redirected our judges to the questionnaire. In order to avoid order effects 10 questionnaires were created featuring 10 permutations of the children's 10 movies (5 from each condition). These permutations were created by following a 10x10 *Latin square* matrix ensuring that the movies' position rotated evenly in the questionnaires (Winer, Brown, and Michels 1962).

To structure our explanation of the process judges followed when conducting their evaluation, we will use the questionnaire's layout. This questionnaire had three stages:

- **General information** - The questionnaire started by presenting the instructions which described the evaluation process to judges. When judges finished reading these instructions, their assent to participate allowed them to proceed to the next stage. It is important to note that the answers to these questionnaires were anonymous and were used only for academic purposes;
- **Demographic information** - After assenting to participate, judges provided some demographic information regarding their age, gender, occupation and work experience (in years). This information could prove important while exploring the data for interesting patterns. The following stage in the questionnaire was rating the children's movies;
- **Rating movies** - Evaluating the stop-motion movies occupied the majority of the judges' time. Each judge rated all 10 of children's movies (five from each condition). This evaluation was carried out by viewing each movie and rating it according to a continuous scale between 0.00 and 10.00. As discussed, these movies should be rated by comparison to each other, ignoring any external standards. To facilitate this comparison, all movies were presented on the same page, requiring only scrolling to a given movie to adjust its rating. This encouraged judges to iterate through their ratings and find the right balance for all their ratings. Judges were also able to relate up to three adjectives to each movie. This was intended to evidence patterns between certain word categories and the judges' ratings or a movie's test condition. In order to ensure fair ratings were assigned to the movies, *judges were blinded regarding the condition to which the movies belonged to*.

Results: The first step in our analysis of the collected ratings was calculating their inter-judge reliability using the Cronbach's coefficient alpha (Hennessey, Amabile, and Mueller 2011). This ensures that the ratings issued by our panel were reliable. The reliability was calculated separately for each condition, resulting in a agreement value of α = 0.68 for the autonomous condition and α = 0.7 for the non autonomous condition. These values approximate a Cronbach's coefficient alpha value of 0.7 and can therefore be considered as representing a good level of inter-judge agreement (Nunnally 1975).

Due to our panel's small sample size, a non-parametric Mann-Whitney U test was used, evidencing no statistical difference between the ratings of movies created in each condition, $U = 944$, $p = 0.576$, $r = 0.06$. Although not statistically different, the mean ranks of the judges' creativity ratings are higher for movies created in the autonomous condition (*Mean rank* = 47.02) when compared to those created in the non autonomous condition (*Mean rank* = 43.98). Given a low volume of answers, no meaningful associations could be drawn between the adjectives we collected and the movies' test condition or ratings. Although these results suggest that there is no statistical difference between the conditions, a study with a bigger number of judges should be conducted to validate Cubus' impact in the creative product as being significant or not. This panel should also feature a more even work experience among the judges, in order to produce more consistent ratings. Another aspect we consider important when producing creative movies with Cubus, is children's interaction time with Cubus' agents. Despite the sessions' one hour duration, the task's high complexity reduced the amount of time children spent with our agents. During the sessions, children had to learn how to use Cubus, learn the techniques necessary to produce a stop-motion movie, create the movie with our agents and edit it. It would be interesting to conduct a study with longer interactions with our agents, as this should ensure that children could fully understand and take advantage of Cubus' functionalities.

Conclusion

With this work, we present *Cubus*, a system designed to stimulate children's idea generation during storytelling. Cubus is comprised of a virtual environment and autonomous agents that children interact with through a touch interface on an Android™ tablet. Cubus' innovative component concerns the autonomous agents whose behaviors were designed to stimulate children's creativity. We conducted a study evaluating the creative process of idea generation in children while interacting with Cubus. In this study we also analyzed the movies children created during their interaction. Regarding the creative process, the results seem to show that children are able to generate a significantly higher number of ideas when interacting with the autonomous agents compared to the control condition in which the agents were not autonomous. On the other hand, the results relating to the creative product did not evidence a significant difference in the movies' creativity levels across conditions. We consider that conducting another evaluation with a more numerous panel of judges is advisable in order to consolidate this result.

Contributions

In addition to our study's results, this work offers three major contributions within the context of computational creativity, Creativity Support Tool (CST) development and intelligent virtual agents:

- **Development methodology** - The methodology followed during our development was both iterative and user centered. To this end, several evaluations were carried out: co-design study, usability testing and final evaluation. The first two stages of our evaluation were aimed at informing our design and ensuring that our tool was accessible to the end user. The final evaluation of Cubus was conducted to validate our study's hypotheses, analyzing two different aspects of creativity. This methodology can be applied to the development of any digital tool that attempts to assist the user, regardless of the research field;
- **Evaluation methodology** - In order to conduct our evaluation of creativity with Cubus, we presented a methodology that evaluates two aspects of creativity: the creative process and product. Additionally, we describe a practical implementation of this methodology, that describes the steps taken during our evaluation as well as some means which allow implementing the suggested evaluation techniques. This methodology could prove useful in the evaluation of other works in the field of CST development;
- **Tool for creative enhancement** - Cubus is a pioneering effort in the study of group creativity with the aid of autonomous embodied agents. This work evidenced how autonomous agents are an interesting characteristic to consider in the design of CSTs. This effort contributes toward the development of CSTs and broadening the use cases in which virtual agents can help users.

Future work

With regard to future work, we consider important carrying out a study where children have more time to understand Cubus and how its agents work. This should help children take full advantage of Cubus which could result in a product with higher creative levels.

Additionally, this work will be complemented by analyzing the children's creative abilities. This will be achieved by analyzing a Test for Creative Thinking - Drawing Production that was administered at the beginning and end of our sessions to each child participating in the study. This test should evidence differences in each child's creative potential between the first application, before the interaction with our system and the last application, which followed the interaction with Cubus (Urban 2004).

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