Embodying Digital Creativity: Designing Computer Tools to Support Spontaneity and Creative Work in the Digital Arts

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Introduction

“An essential voice in creatively based thinking is the language of the body...” (Johnston, 1986, p. 21). Depending on your background, claims such as this may seem obvious or surprising, but are they actually true and can they be validated? If true, can we use this insight to design computational tools that better support creativity? These questions drove an extended investigation of how increasing embodiment impacts people’s creative process when using computational tools for artistic tasks. Unlike Lise Amy Hansen's Sync tool (see Chapter 8), which aims to enhance creativity in dance and the movement arts, our work is focused on supporting creativity for common tasks in computer graphics and animation. During this work, we built software tools designed to support greater spontaneity and embodiment: features common in artistic practices like theatre, but poorly supported in most computational tools. We then studied how working with these tools impacted users’ creativity. Preliminary results indicate that embodiment does appear to enhance certain factors related to creativity. This chapter will first summarize some of the relevant theoretical background, then describe our investigations on the role of embodiment in supporting creativity and conclude with a discussion of lessons learned and next steps.

In developing a framework for creativity, Johnston (1986) breaks the creative process into a progressive series of stages, listed with their associated activity in brackets: pre-axis (incubation), early-axis (inspiration), middle-axis (perspiration), late-axis (finishing and polishing) and integration (into a personal and cultural context). It is the early phases of incubation and inspiration during which embodiment and spontaneity seem to have an especially strong role to play. These stages are also poorly supported by computer tools for graphics and animation. Indeed, the early development of animated scenes is dominated by creative exploration, but this work is normally done entirely outside of the realm of computational tools (Panko 2005, Kapijimpanga 2005, Burke 2007, Brown 2008), by acting out the scene, seeking reference footage, writing or drawing thumbnail sketches. Computer tools are only used once the major decisions have been made, after much of the creative exploration is done. Worth noting, the early period of heightened creativity will often require two out of the five days spent on a scene in a common animation cycle (Burke, 2007).

Computer tools see limited use in the main creative phase in part because they are slow to use and limit spontaneity. Exploration through means such as acting is also fully embodied, versus an almost entirely mental process when the animator begins to work in a computer keyframe system. The gestures of moving the mouse to adjust a control have no correspondence to the intended motion of the character. Along with offering advantages related to response time and aiming accuracy (Mazalek et al., 2007), embodied exploration allows the animator to access a much wider range of faculties such as: psychological recall, muscle memory, proprioception, visual feedback and the felt effects of gravity. Through improvised movement, various possibilities are developed, examined, enhanced and/or rejected (Halprin, 2002). Movement metaphors can express thoughts that are difficult to communicate otherwise (Ellis, 2001); “What is very real and understandable in movement does not necessarily have an equivalent in words” (Blom and Chaplin, 1988, p.ix). The sections that follow further elaborate on the role of spontaneity and embodiment in creative activity, survey relevant background material and describe our experiments to date building novel tools.

The Case for Embodiment and Spontaneity

Techniques that encourage spontaneity and those that rely on embodiment are often the same or closely intertwined, with embodiment appearing to support spontaneity.

As discussed by Shusterman (2008) and Dissanyake (1992), we have inherited a Western philosophical legacy, starting from Plato and being reinforced by Descartes, that denigrates the role of the body while elevating the role of the mind. While they observe that this bias has been challenged by many philosophers in the last hundred years (with some going so far as to develop body based philosophies of aesthetics), its legacy is no doubt reflected in the development of computer technology, where early artificial intelligence was developed largely without reference to a body and the dominant computer interface remains a keyboard and mouse. Most computer systems take a fundamentally disembodied view of their users.

As Richard Shusterman (2008) points out, this view is deeply limited, as "...the body constitutes an essential, fundamental dimension of our identity. It forms our primal perspective or mode of engagement with the world, determining (often unconsciously) our choice of ends and means..." (p.2-3). Theatre has often taken a deeply embodied approach to exploration. For instance, the renowned play- wright and director Bertolt Brecht would not allow discussion in rehearsal. All ideas had to be tried – in the body. In a workshop, director, movement educator and Grotowski disciple Jennifer Tarver (Tarver and Bligh 1999) instructs with the perhaps unintuitive phrase "The body is smarter than the mind." For acting theorist and director Jerzy Grotowski, the goal of a training method is to develop the plasticity of the body such that the actor perceives a stimulus and reacts, rather than perceives a stimulus, consciously thinks about it, and then reacts (Grotowski, 1968).Such methods try to access a pre-conscious thought, the flow of ideas that comes before conscious deliberation. Important to creative engagement and inspiration, this idea will be further explored in the discussion of spontaneity. Johnston argues that in the Pre-axis stage of the creative process, knowing is based on the "kinesthetic language of the body" (1986, p.84).

Numerous facilities within our bodies are often ignored in our society. Beyond the five classical senses, neurophysiology identifies the somesthetic senses that "are often divided into exeroceptive (relating to stimuli outside the body and felt on the skin), proprioceptive (initiated within the body and concerned with the orientation of the body parts relative to one another and the orientation of the body parts in space), and visceral or interoceptive (deriving from internal organs and usually associated with pain)." (Shusterman, 2008, p.2).

Embodiment and Spontaneity: support tools

Warren Lamb, a contributor to the development of Laban Movement Analysis, divided movement into two broad categories: gestures and posture changes (Lamb, 1965). Gestures are movements of parts of the body – arms, legs, and head. Postural movements involve the entire body, including an engagement of the core. Lamb argues that effective, beautiful, expressive movement includes postural adjustments even while gesturing. Following this, tools that support embodiment will be those that naturally allow postural movement during use. As an added criterion, the movement of the body should also align with the attribute being controlled. For instance, a fully embodied pushing of a button is unlikely to have the same benefit as a system that more directly maps the timing of body movements to the timing of attributes in the application.

Dance professor Della Davidson suggests that “creativity is about the ability to play, and the ability to be spontaneous to your environment and to the tools you are working with” (2003). Spontaneity is tightly tied to creativity in the performing arts and psychologists Runco and Sakamoto suggest “creativity may depend on spontaneity” (1999, p.62). LeCoq claimed the fundamental goal of his renowned school for actor training in Paris was creativity and relied extensively on play and spontaneity, arguing that “...through improvisation, [they] externalize what is latent within the students” (2002, p.27). Grotowski similarly put spontaneity at the core of the creative work of an actor. Their embodied approaches reinforce the linkage between the body and spontaneity in creative work, and the role of avoiding deliberative thought in creative exploration.

Keith Johnstone, one of the founders of improvisational theatre, similarly supports the importance of spontaneity and warns about the danger of deliberative thought in inhibiting creativity. He writes: “Imagination is as effortless as perception, unless we think it might be ‘wrong’, which is what our education encourages us to believe. Then we experience ourselves as ‘imagining’, as ‘thinking up an idea’, but what we’re really doing is faking up the sort of imagination we think we ought to have” (1981, p.80).

Tools that support spontaneity must allow the real-time exploration of ideas. This implies that they must A) be real-time and interactive, and B) allow control over a significant portion of the total creation in real-time such that the user has the experience of direct creation rather than contemplative reflection.

While most industry-standard tools for creating computer graphics, such as Maya or 3D Studio

Max, rely on a traditional mouse and keyboard interface, perhaps extended with a stylus, research and art systems have experimented with more embodied and performative interfaces. Space only allows us to touch on a few computer animation examples from a large body of work. Sturman presents an early survey on computer puppetry (1998). Oore et al. developed a system that allowed users to puppet a character by moving tubes in 3D space that were mapped to character bones (Oore et al., 2002a, 2002b). Dontcheva et al. developed an animation system that uses a motion capture system to track widgets in 3D space as input (2003). Both approaches rely on layering multiple performances to produce a final animation. Work by Laszlo et al. provides interactive control of physically simulated, planar characters (2000, 2005) using a mouse and keyboard. This approach provides spontaneity, with a still low embodiment interface. Igarashi et al. embed character poses in input space and automatically blend them as the user drags a mouse pointer through this space (Igarashi et al., 2005). Neff et al. tackle one of the limits of mouse-based input by developing methods that allow the two degrees of freedom of mouse input to be mapped to a much larger number of degrees of freedom in a human character model (2007). Other work has explored performance as an effective means to time animated motion (Metoyer and Terra 2004, Baecker 1974).In the realm of painting, Keefe et al. (2001) created an embodied interface that allows users to paint 3D scenes while working in a Cave.

Recent work has focused on designing tools that support creativity. Shneiderman (2007) emphasizes the importance of rich history-keeping and tool design that is straightforward enough for novice users, yet powerful enough for experienced ones. Constraints play an important part in the creative process and serve to establish an artistic foundation. Task constraints, such as choice of medium and style, serve as loose guidelines for the artist’s creative process (Stokes, 2005). Work focused on embodied interfaces discusses how exertion can be considered an aid, rather than a hindrance, when using embodied interfaces. Expecting a certain amount of exertion can encourage one's positional awareness (Lyons et al, 2012).

Measuring creativity

Psychologists have developed a wide range of techniques for evaluating creativity[i] . The techniques are aimed at answering varied questions, such as "How creative is a particular individual?" "What personality traits correlate with creativity?" or "Can providing particular information increase creativity?" Our work is focused on a specific issue: how does the use of a particular tool alter a user's creativity? The process, user experience, and final output are all distinct components when doing creative work, and one alone should not be treated as a definitive authority (Cropley, 2000). Plucker (1999) describes several approaches for measuring creativity. One of the most common and well validated psychometric measures for evaluating creativity is to measure how divergent someone's thinking is, as this has been shown to be a good proxy for creativity. A second technique is to examine the product of the creative process and determine how much creativity is embedded in it. This is generally done by external judges. This approach is based on the view that "People know creativity when they see it" (1999, p.45), which has been at least partially validated and is widely used in practice. The Creativity Support Index (CSI) has been proposed as a standardized instrument for evaluating creativity in software (Carrol et al., 2009). It is based on research that identifies key factors that support creative work: exploration, enjoyment, collaboration, expressiveness, immersion and results-worth-the-effort. With it, a subject weights the importance of these factors for her given task and also how effectively the tool supports them. The CSI then calculates a rating between 0 and 100, which can be reliably compared with scores for other tools.

Our first study uses the CSI. While prototyping the second study, subjects reported a tendency to repeat answers in the CSI, especially those used to weight components, after responding to the same set of questions multiple times after sequential tasks. We therefore extracted a shorter set of questions based on the CSI, eliminating questions on collaboration, which is not possible in our tool, and component weighting. This leaves five specific factors for our subjects to rate, as detailed in Table 1. We believe this approach provided a good indication of self-reported creativity levels with less risk of survey fatigue.

Experiments with a 3D Animation Interface

In our first exploration with more embodied interfaces, we created a system for quadruped animation dubbed “CAT” (Figure 1). The system used a tracked Wiimote to provide six DOF continuous input (position and orientation), along with button controls. Animation was produced in a layered approach where part of the cat’s motion was specified and then

Measure	Question
Output Satisfaction	I was satisfied with what I created using this system
Exploration	It was easy for me to explore many different ideas, outcomes, or possibilities
Use Frequency	I would be happy using this system on a regular basis for this type of activity
Creativity	I was able to be very creative while doing this activity
Absorption	I became so absorbed in the activity that I no longer had to concentrate on

	using the controls

Table 1: the five questions asked after each task

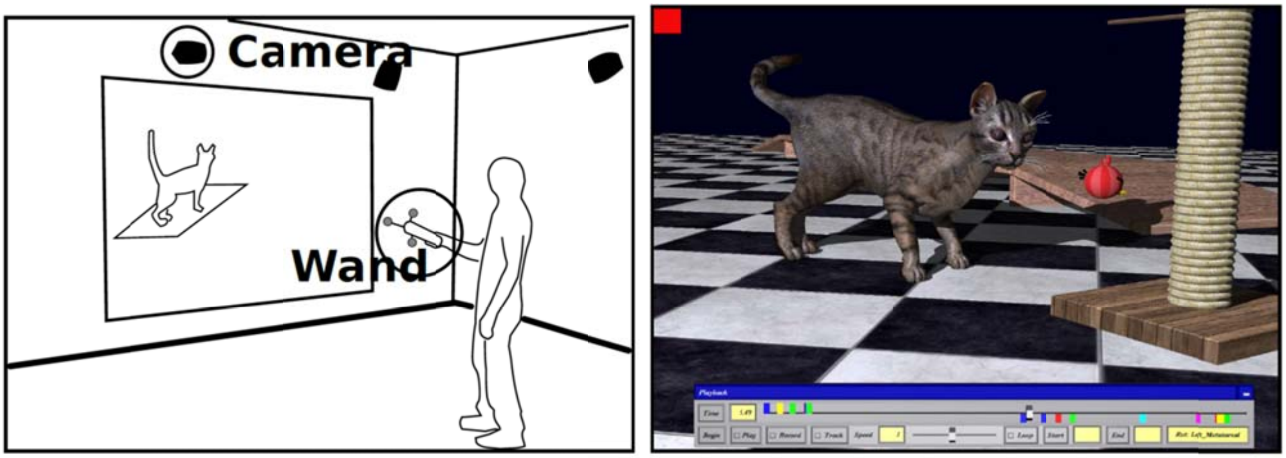

Figure 1: The physical workspace of CAT is shown on the left, and a screenshot of the produced animation is on the right.

additional details were added in subsequent layers. Controls included automated locomotion generation in which the user would draw a path and the system would generate the correct gait along the path; multi-joint controls, where the user could move a paw to control the cat's leg or adjust the height of the cat; and single joint controls that vary a single degree of freedom. We evaluated the system with ten participants across five different tasks, using the Creativity Support Index to judge how well it supported creativity[ii].

The most enjoyable tasks according to CSI ratings were those that were well embodied and responded directly to the user's movement. The tools that affected multiple joints were rated the most creative. This suggests that our mostly novice users require some amount of automation to convey their creative ideas. Survey responses indicated both that users had a significant preference for the automation of multiple joint control over single joint control and that CAT's automation impacted participant's creativity.

Embodied Interfaces for Sketching, Editing and Puppeteering

We developed a software platform called Sandbox (2013) that supports basic curve and polygon drawing. The platform also allows editing through the use of deformation lattices and animation by puppeteering a physically simulated marionette. The system supports two main forms of input: a mouse and keyboard, and a pair of tracked Wiimotes. The position, orientation and input buttons of the Wiimotes are all used as input. The input volume can be scaled so that the entire screen can be spanned with a single arm movement while the user is seated (small) or the user needs to walk to span the screen (large). All output is generated on a 2D plane so that the user does not need to deal with the added complexity of depth control.

Comparative studies were performed with the system using a within-subject design in which subjects would use a different interface to complete tasks during two separate visits to the lab. In one experiment, we compared the mouse and keyboard to a tracked Wiimote. In the second, we compared Wiimotes in a small volume where the subject was seated to a large volume where the subject was standing and needed to locomote to cover the screen.

The less embodied interface in the first experiment is a 3-button mouse and keyboard with an LCD monitor for display[iii]. Directly mapping input movements to the large screen encourages users to move throughout the environment to span the screen. A 12 camera Vicon optical motion tracking system is used to provide accurate position and orientation information for the Wiimote.
For the 3D interface, Sandbox orthographically projects the device location onto a screen position, and displays a glyph at that cursor location. A scale factor is introduced that allows the

input space to be made smaller than the screen space in case subjects cannot reach the top. This scale factor is further reduced to allow users to span the screen while seated for the less embodied interface in Experiment 2.

We instruct participants to complete (in order) a drawing task, an editing task, and an animation task. No task is allowed to continue for more than 15 minutes. In the drawing task, users are instructed to draw emotionally expressive faces. Users can draw curves and shapes, scale, rotate and translate them. Editing is done by manipulating free-form deformation lattices (Figure 2) (Parry and Sederberg, 1986). Each lattice contains a 3 × 3 grid of control points for a set of Bézier curves that deform the underlying shapes as the control points are moved. The user can select and move arbitrary sets of control points. Users edit a template face to produce emotional expressions. The first task is an animation exercise where users puppeteer a marionette. As discussed below, the controls differ slightly in the two experiments so that the first Wiimote interface is comparable to a mouse in its degrees of freedom. The stick figure marionette is physically simulated and collides with the screen edges for enriched interaction, but not itself. Written and oral instructions on the interface controls were provided prior to the beginning of each task. Subjects were allowed to practice the controls and ask questions. At the end of each task, subjects rated the prompts in Table 1 on 5-point Likert scales, and also completed an exit survey rating their preference for each interface on each task.

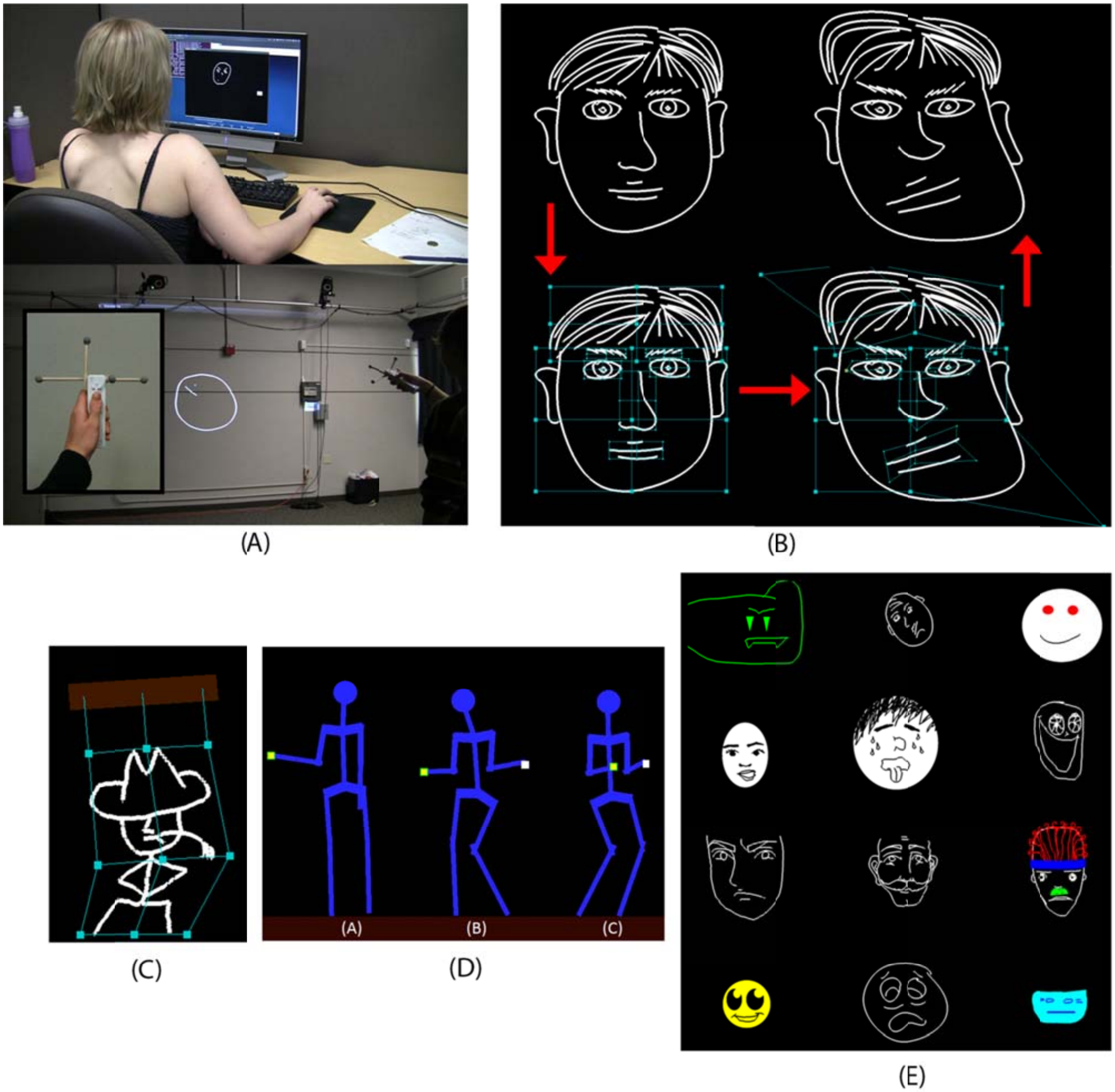

Figure 2: Sandbox. A) The desktop interface (top) and Wiimote interface (bottom, with controller inset). B) Free-from deformation lattices for editing. C) The marionette used in Experiment 1. D) The marionette used in Experiment 2. E) Sample face drawings from Experiment 1.

Care was taken to minimize unwanted experimental effects. Subjects could not complete both sessions on the same day. The intersession interval encouraged learning decay between tasks and reduced fatigue effects. In each experiment, half the subjects started with one interface and half with the other to minimize ordering effects. Prior to each task, subjects were presented instructions on the interface controls and given time to practice to ease learning requirements. Finally, subjects were advised that about 45 minutes was allocated per session to avoid developing fatigue from extended use. These decisions are based on best practices in HCI research methods (Lazar et al., 2010).

Experiment 1: Mouse and Keyboard vs. Standing Interfaces

Some unique qualities of the first experiment are described here, but it largely follows the aforementioned general method. It compares a standard mouse and keyboard interface with a more embodied Wiimote where the input volume is scaled so that the user must take steps to span the entire screen. Given the mouse's dominance in desktop computing, we find it an appropriate device for the 2D interface. A pen and tablet could have been configured for drawing and editing, but a mouse offered more comfortable control for the animation task, and we wished to use a single input system for each session. Figure 2 shows both interfaces in use.

The marionette system for this experiment was designed to use one Wiimote and only vertical and horizontal translation to maintain the same number of degrees of freedom with the mouse interface. The marionette is constructed using a deformation lattice with rope-like constraints between control points and a top handle that is moved by the user translating the mouse or Wiimote, as shown in Figure 2. Handle rotation is controlled by rotating the mouse scroll wheel or axially rotating the Wiimote.

Seven women and five men, age 18 to 27, participated in the study as paid subjects. Six were randomly assigned to use the mouse in their first session, while the remaining 6 were assigned to use the Wiimote first. The intersession intervals ranged from 1 to 7 days.

We choose a parametric test for our data as it has been shown to be effectively equal in power to non-parametric tests such as the Wilcoxon signed-rank test (Kaptein et al., 2010, Carifio and Perla, 2008). The survey responses are analyzed separately for the five creativity support factors. Table 2 summarizes the results of paired t-tests on the populations from these three tasks, including sample means, standard deviations, and Cohen's d effect size. We designate small, medium, and large effect sizes as 0.2, 0.5, and 0.8 respectively.

Grouping performance by interface across all three tasks, all factors except for Exploration were rated significantly higher for the embodied interface. The mean ratings for the embodied interface are all higher than the paired mouse and keyboard interface.

For the drawing task, the results indicate a statistically significant higher rating for the embodied interface on the Creativity factor[iv], but not significant

	Question	2D	3D	t-test	d
Drawing	Output Satisfaction	$\mu = 3.25, \sigma = 1.14$	$\mu = 4.0, \sigma = 0.74$	*$t = 2.14, p = 0.06$*	0.36
	Exploration	$\mu = 3.5, \sigma = 1.38$	$\mu = 3.92, \sigma = 0.79$	$t = 1.16, p = 0.27$	0.18
	Use Frequency	$\mu = 3.0, \sigma = 1.28$	$\mu = 4.0, \sigma = 0.85$	*$t = 2.17, p = 0.05$*	0.42
	Creativity	$\mu = 3.16, \sigma = 1.21$	$\mu = 4.0, \sigma = 0.74$	**$t = 2.27, p < 0.05$**	0.39
	Absorption	$\mu = 2.92, \sigma = 1.24$	$\mu = 3.67, \sigma = 0.78$	$t = 1.52, p = 0.16$	0.34
Editing	Output Satisfaction	$\mu = 3.17, \sigma = 1.27$	$\mu = 4.17, \sigma = 0.72$	*$t = 2.03, p = 0.07$*	0.44
	Exploration	$\mu = 3.67, \sigma = 1.27$	$\mu = 4.17, \sigma = 0.72$	$t = 1.32, p = 0.21$	0.24
	Use Frequency	$\mu = 3.25, \sigma = 0.97$	$\mu = 4.08, \sigma = 0.51$	**$t = 2.42, p < 0.05$**	0.48
	Creativity	$\mu = 3.58, \sigma = 0.9$	$\mu = 4.08, \sigma = 0.9$	$t = 1.20, p = 0.26$	0.27
	Absorption	$\mu = 2.5, \sigma = 1.24$	$\mu = 3.83, \sigma = 0.58$	**$t = 3.22, p < 0.01$**	0.57
Animation	Output Satisfaction	$\mu = 3.67, \sigma = 1.15$	$\mu = 4.0, \sigma = 0.74$	$t = 1.08, p = 0.30$	0.17
	Exploration	$\mu = 3.92, \sigma = 1.16$	$\mu = 4.08, \sigma = 0.29$	$t = 0.48, p = 0.64$	0.10
	Use Frequency	$\mu = 3.5, \sigma = 0.90$	$\mu = 4.08, \sigma = 0.51$	*$t = 2.03, p = 0.07$*	0.37
	Creativity	$\mu = 3.42, \sigma = 1.0$	$\mu = 4.0, \sigma = 0.60$	$t = 1.73, p = 0.11$	0.33
	Absorption	$\mu = 3.42, \sigma = 1.24$	$\mu = 3.92, \sigma = 0.79$	$t = 1.15, p = 0.27$	0.23
Composite	Output Satisfaction	$\mu = 3.36, \sigma = 0.89$	$\mu = 4.06, \sigma = 0.56$	**$t = 2.31, p < 0.05$**	0.42
	Exploration	$\mu = 3.69, \sigma = 0.84$	$\mu = 4.06, \sigma = 0.43$	$t = 1.32, p = 0.11$	0.27
	Use Frequency	$\mu = 3.25, \sigma = 0.86$	$\mu = 4.06, \sigma = 0.33$	**$t = 3.05, p < 0.01$**	0.53
	Creativity	$\mu = 3.39, \sigma = 0.85$	$\mu = 4.03, \sigma = 0.62$	**$t = 2.10, p < 0.05$**	0.40
	Absorption	$\mu = 2.94, \sigma = 0.98$	$\mu = 3.81, \sigma = 0.5$	**$t = 2.73, p < 0.05$**	0.49

Table 2: Analysis of responses to survey questions for each task using paired t-tests. Survey responses were on the 5-point Likert-type scale from 1 to 5; 1 indicates strong disagreement with the question and 5 indicates strong agreement. μ is mean response, σ is standard deviation, effect size is Cohen's d. N = 12 for all analysis measures, so DOF= 11 for t-tests. Bold indicates significance ($p < 0.05$), italics indicates tendency ($p < 0.1$)

differences for Output Satisfaction and Use Frequency. These three factors all have effect sizes between small and medium. The analysis for the editing task indicates a statistically significant preference for the 3D interface on the Use Frequency and Absorption and a tendential difference for Output Satisfaction. Output Satisfaction and Use Frequency have effect sizes slightly below medium, and Absorption has a large effect size. For animation, only Use Frequency has a tendential difference, while Use Frequency, Creativity, and Absorption have effect sizes between small and medium.

Finally, the exit survey responses are analyzed as single-sample t-tests using a hypothetical mean of 3 to indicate equal preference for the interfaces, 1 representing preference for the mouse and 5 for the embodied interface. There were no significant preferences for either interface in any task, although editing[v] animation[vi], and overall[vii] preferences were tendentially higher for the embodied interface.

Use Frequency showed a preference for the embodied interface over the mouse and keyboard. A possible explanation portrays the mouse as ubiquitous and less interesting than the more novel Wiimote. However, survey responses also describe the embodied interface as “more intuitive” and especially praise the naturalness of rotation operations, suggesting these results are not entirely from novelty. This preference for regular use of the embodied interface occurs despite higher fatigue, suggesting that the characteristics unique to using an embodied interface, such as exertion, may contribute positively to the user’s experience.

We thought the animation task would most clearly benefit from embodied interaction, but only Use Frequency showed a tendency for preference for the embodied interface on this task. High Absorption and Exploration ratings for both interfaces indicate that the task is quite engaging. Subject comments revealed important difference between the two interfaces, noting that the 3D interface “made it easier to imitate a walking motion by making it easier to rotate while moving the character,” and that it was “particularly intuitive and engrossing. You felt like you were in more direct control of the character, having to move your body in similar patterns to accomplish the intended motion.” Not all participants favored embodiment, one finding the wrist rotation difficult and one preferring the familiarity of the mouse. Based on qualitative feedback, self-reported measures, and user preference, we preliminarily suggest a relation between task complexity and the effect of embodied interfaces. For embodiment to have a meaningful impact on creativity, tasks may require a minimum level of complexity that was present for the drawing and editing tasks, but not for animation. Reducing the embodied interface to only provide x, y translation and axial rotation may also have limited some of the benefit a more full version of embodiment might provide.

While still preliminary, these results support the notion that embodied interfaces better support factors related to creativity. Our next study seeks to understand the role played by the specific form of embodiment.

Experiment 2: Small Volume Seated vs. Large Volume Standing

To better understand the role of specific variations in embodiment, we designed and performed a comparative study in which the interface is the same in both tasks, but the input volume is scaled. In the small condition, the person can span the entire input space with an arm movement and is seated. In the large condition, the user needs to walk to cover the whole input space, leading to more body use and greater embodiment.

Subjects were first asked to draw lines connecting pairs of colored points placed at arbitrary distances. The same set of points was used for every subject. This task allowed participants to familiarize themselves with the application. It also provided quantitative data on how the two interfaces perform.

The drawing and editing tasks are the same as Experiment 1. The animation task was enhanced using two Wiimotes. One controller translates and rotates the marionette's overall pose by transforming the head and neck, and the other allows the user to move one or two limbs, symmetrically or in parallel. Participants were instructed how to use the controls, given practice time, and then instructed to perform basic motions such as waving and gesturing. Once comfortable, the prompter asked them to make the marionette dance to a piece of music for 90 seconds. After this, participants use the marionette as an avatar and held a short dialogue with the prompter.

Eleven women and 14 men (ages 18 and 39) participated in the study as paid subjects. Subjects attended two sessions, completing each task (drawing, editing and interaction) with one interface per session. Thirteen were randomly assigned to begin with the seated interface, 12 with the standing interface. After all subjects completed the experiment, the creativity of their output was judged.

Analysis on the performance measures indicates no significant difference between average time spent drawing lines[viii] or residual error between lines and targets[ix]. This indicates that people were equally capable of drawing lines with either interface.

Participants rated their interface preference for each task on a scale from 1 (seated interface preferred) to 5 (standing interface preferred). Based on a one-sample t-test with a mean of 3 (“equal preference”), results show a significant preference for the standing interface for the drawing[x] and animation[xi] tasks, and it is the overall preferred interface[xii].

As in the first experiment, survey responses are analyzed with paired t-tests for each factor for each task, as well as a composite measure across all tasks for each factor. Only Q1 (Satisfaction) for the animation task had a significantly different rating, showing preference for the standing interface[xiii]

The mean responses for each factor across each task are all greater than the neutral value 3, except for Q5 (Absorption) on the standing animation task, indicating a favorable view in general of how the tools support these creativity factors.

Task engagement or "flow", a term borrowed from psychology to describe when a person is highly involved in a task (Chen, 2007), can indicate a high level of absorption that is an ingredient in creative work (Csikszentmihalyi, 1997). The prompts for the drawing and editing tasks instruct subjects to notify the proctor when they no longer wish to create content. We counted the number of sessions when participants continued past the time limit as an objective measurement of task engagement. Long work times could indicate difficulties completing the task, but since people performed equally well with either interface in the performance task, we attribute differences to absorption.

Participants continued past the time limit in 37 out of the 100 drawing and editing tasks. 13 were from seated sessions and 24 from standing. A Chi-square test between interface and task timeout revealed that the number of timeouts significantly diff between interfaces[xiv]. Tasks performed with the standing interface were more likely to continue until timeout.

Our survey tool is only capable of providing self-reported creativity measures. To explore whether there are objective differences in the output with different interfaces, we had a panel of three graduate art students rate the creativity in collections of output (drawing, editing and animation) from each interface for each subject. Results did not reveal a statistically significant difference.

The performance measure suggests that participants could work equally well with either interface, noteworthy given the quite different movements required to span the different input spaces. With regards to creativity, subjects appeared to create similarly creative output with each interface and only the Satisfaction factor on the animation task was rated significantly higher for the more embodied interface. However, participants were significantly more likely to work with the standing interface past the time limit. As performance on the interfaces is similar, this appears to indicate a greater level of immersion, a factor related to creativity. Participants also indicated a preference for the standing interface on the drawing and animation tasks, as well as overall. In addition, the creativity factors were rated above neutral on average for every interface/task combination except for Absorption for the standing interface on the animation task (29 out of 30 tasks), suggesting both interfaces support creativity. Taken together, this data is not sufficient to conclude that the large volume interface will have a specific impact on creative performance, but does suggest that people prefer the large volume, standing interface and appear to be more engaged while using it. Further investigation appears worthwhile.

Additional insight can be garnered from user feedback. After completing the seated animation task, one user remarked “My arm wasn’t too tired... but it was just harder to animate someone who was standing up while I was sitting down.”, indicating that fatigue wasn’t a factor, but the larger, standing space felt easier, at least when it matched the task. Participant feedback suggests standing is a more natural choice for interactive tasks. One user notes that “Standing allowed me to be much more expressive, and the movements and gestures were much more natural. Sitting, it was more a matter of thinking about the gestures, rather than spontaneously doing them.” Another subject, whose first session used the standing interface, reported after completing the animation task while seated: “I felt like I did not have to think about it as much when I did [the task while] standing, even though it was the first time using it then.” These comments indicate that the large volume interface may bring about a different form of engagement, one more embodied and less based on conscious, deliberative thought. This is exactly the type of transformation sought in much actor training in order to encourage creativity, as discussed in the opening.

We attempted to identify the impact of embodiment on creativity by using experiments to compare traditional and embodied interfaces for creative tasks in digital media. Experiment 1 showed a significant preference for the more embodied interface across a range of factors, including self-reported creativity levels and task absorption. The picture in Experiment 2 is less clear, with limited differences on creativity factors, but evidence of greater engagement and a clear preference for the larger volume interface over the small volume. Perhaps most interesting, participant comments suggest that their manner of engagement may be different with the change in input volume.

Discussion and Paths Forward

This chapter describes our initial explorations of the relationship between embodied interfaces and creativity support. There is a clear theoretical basis for expecting that increased embodiment can help support creativity. While still preliminary, our results indicate that embodied interfaces do offer value in enhancing creative tasks and further research is likely to be fruitful.
Thoroughly investigating these issues presents numerous challenges. First, a definition of embodiment is required. Interfaces lie on a spectrum from those that require little movement to those that engage the entire body. Second, particular types of activities must be identified as some tasks may benefit more from embodiment than others. While the comparative approach adopted here leads to clean experimental designs, it restricts the range of embodiment that can be supported as two interfaces must offer comparable affordances. This is particularly limiting when one interface is a mouse, with only two degrees of freedom, but in general limits the ability to create

complex embodiments, optimized for a particular task (for example, acting out the movements of a cat). Instead of the comparative experimental approach, ethnographic techniques that seek to understand users' thought processes may prove useful. As a final note, the adoption of more embodied interfaces may have health repercussions as well as impacts on creativity. There is growing concern about the negative health effects of a sedentary lifestyle (Thorp et al., 2011). Given the importance of computation in modern work, more embodied ways to interact with computers may offer significant health gains.

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[i] For a survey of psychometric techniques, see (Plucker, 1999); for experimental techniques, see (Runco and Sakamoto, 1999); or for a broad overview, see (Sternberg, 2003).

[ii] Full details on the system and experiments can be found in (Martin and Neff, 2012).

[iii] The more embodied interface is a single motion-tracked Wiimote (two are used during the Experiment 2 animation task) with a projector with a 124 in. × 93 in. screen for display.

[iv] with tendential ($p < 0.1$)

[v] $t(11) = 1.39, p < 0.1, \mu = 3.67, \sigma = 1.67$,

[vi] $t(11) = 1.76, p < 0.1, \mu = 3.83, \sigma = 1.64$

[vii] $t(11) = 1.65, p < 0.1, \mu = 3.83, \sigma = 1.75$

[viii] $t(24) = 1.19, p = 0.24, \mu = 0.08, \sigma = 0.33$

[ix] $t(24) = 1.03, p = 0.31, \mu = 0.48, \sigma = 2.34$

[x] $t(24) = 2.72, p < 0.05, \mu = 3.88$

[xi] $t(24) = 2.52, p < 0.05, \mu = 3.76$

[xii] $t(24) = 2.34, p < 0.05, \mu = 3.72$

[xiii] $t(24) = 2.06, p < 0.05$

[xiv] $\chi 2(1, N = 100) = 4.29, p < 0.05, \varphi = 0.23$, odds ratio 2.62