PREPRINT: Found Object Puppeteering as a Tool for Rapid Movement Sketching in 3D Animation

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Figure 1: Incorporating physical materials – such as a stretchy band, weights, fabric – into the movement sketching process has the potential to enable novice animators to deeply engage with movement qualities. Left: Tangible controllers allow for embodied manipulation of 3D digital models. Center: “Found objects” such as a stretchy band act as material jigs. Recording the movement of a digital character while pulling the band adds an ineffable quality of tension to the movement. More importantly, playing with physical materials enhances the ideation process for novice animators. Right: Novice animators using the tool for the first time experimented with using material jigs in diverse ways. Clockwise from upper left: Using a stick to constrain movement along a path; dangling the controller to allow gravity to generate novel movements; dropping the controller into a piece of fabric; and holding a set of weights to embody the experience of a ‘heavy’ or ‘sad’ character.

ABSTRACT
Both expert and novice animators have a need to engage in movement sketching – low-cost, rapid iteration on a character’s movement style – especially early on in the ideation process. Yet animation tools currently focus on low-level character control mechanisms rather than encouraging engagement with and deep observation of movement. We identify Found Object puppeteering – where puppeteers manipulate everyday physical objects with their hands – as a creative practice whose use of material “jigs” is uniquely well-positioned to scaffold the novice animator’s developing skills. In this paper, we draw on the practice of an expert puppeteer practitioner to inform the design of a system that incorporates physical objects into the animation workflow to scaffold novices into diverse movement exploration while manipulating digital puppets.

CCS CONCEPTS
• Computer systems organization → Embedded systems; Redundancy; Robotics; • Networks → Network reliability.

KEYWORDS
animation; puppetry; creativity support tool

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1 INTRODUCTION
In animation, movement is key for conveying a character’s personality, emotions, story, and meaning. However, current animation tools for designing character movement remain challenging to learn, requiring extensive investment in time and effort [8] limiting both their adoption by novice animators, and their usefulness in early ideation sketching even for experts. Additionally, the use of techniques such as creating keyframes and interpolating between them keeps designers focused on low-level mechanisms rather than allowing them to quickly engage in sketching behaviors – early ideation that is quick, exploratory, ambiguous, gestural [2, 3] – a key step in the creative process [3, 19]. Sketching can be understood as a low-cost design strategy that allows experienced sketchers to
engage in a reflection-in-action constructionist process [12], or as early externalizations of an idea, or as filters and manifestations of design ideas [27]. As such, the early ideation sketching process benefits from tools that provide a low threshold [31] and paths of least resistance [31] to expressive behaviours. In this work, we ask the question: How can animation tools scaffold animators towards benefical movement sketching techniques?

Rapid embodied sketching is the domain of another creative field: Puppeteers have been bringing inanimate objects to life to the delight of many for hundreds of years. In Found Object puppetry, everyday materials directly shape the design of compelling characters. For example, a napkin may be crumpled in a particular way and combined with a ceramic cup and a stick to create a fighting character (see Figure 2). Also called “live 3D animation”, this puppeteering technique is a bricolage practice [42] that relies on a “knowing-through-action” [6, 33], reflective conversation with materials [35]. Because it relies on physically manipulating “objects at hand” (rather than requiring a constructed puppet, as in Marionette, Hand and Rod, Costume, or Shadow Puppetry (see Figure 3), this technique is particularly well-suited to supporting quick engagement in embodied movement exploration.

Specifically, we suggest that the materials typically used by Found Object puppeteers could helpfully influence animation techniques, if they could be incorporated into the animator’s workflow. In this paper, we introduce a system for novice digital animators which incorporates aspects of analog, tangible, Found Object puppeteering. The expert Puppeteer we interviewed described the materials that he uses in his practice as helpfully constraining his movements, much like the way that jigs and fixtures support woodworkers by providing selective constraints to motion. While jigs in woodworking are typically solid and hold cutting materials securely in place, and the Puppeteer used soft or flexible materials such as a napkin or a jacket, the core idea of an external tool that helpfully limits movement remains the same. We therefore also refer to the materials we incorporate into the animation process as jigs. We show that by conceptualizing these “found objects” as material jigs and incorporating them into the animator workflow, novices use the materials to engage in embodied exploration to generate movement sketches: using a stretchy band between both arms to create tense, vibratory movement or hanging a controller by a piece of fabric to capture naturalistic pendular effects. Together, tangible animation controllers and material jigs enhance the novice animator’s character design practice and ability to engage in a reflective, embodied conversation with both the digital sketching output and the physical sketching materials themselves [22, 36].

In this paper, we draw on techniques from expert puppeteer practitioners to inform the design of a system that allows novice animators to engage in embodied movement sketching practices. We identify Found Object-style puppeteering as uniquely positioned to contribute character design strategies to the world of animation. We first describe strategies and techniques used by expert practitioners in two distinct but related fields – animation and puppeteering – and describe how the Found Object puppeteering strategy of material “jigs” can be fruitfully imported into the core animation workflow. Next, we describe our authoring tool, PuppetJig, which allows designers to define, layer, edit, and replay motion-tracked character animations via the manipulation of tangible controllers and material jigs. We then share the results of an exploratory evaluation with participants experiencing the tool for the first time. Finally, we discuss how this concept of jigs applies to the world of digital animation, and suggest future directions for exploration.

2 RELATED WORK

2.1 Tangible Tools and Systems

Tangible interfaces have long been recognized for providing benefits in contexts that require experimentation, muscle memory, tacit learning, and the ambiguity and complexity of the physical world [22]. Analog tangible interfaces – such as clay – are known for enabling a rich “conversation with materials” [35] which designers frequently seek to recreate with digital materials [30, 40, 41]. For example, Jones et al. created a system that enables designers to fabricate clay sculptures [18], arguing that an interactive, physical prototype affords a more accurate, iterative, and responsive design process. Raffles et al. introduced Topobo, a tangible interface designed to support children learning about how “balance, leverage and gravity affect moving structures” [34]. Tangible systems also enable the capture of physical performances for archive purposes [9]. ChronoFab is a 3D modeling tool for crafting motion sculptures [20]. Such tangible systems are frequently celebrated for being easy to learn, yet also having a high expressive ceiling [31], which we hope to incorporate into our system.

Tangible systems have been particularly valuable in the context of animation. An early example of a tangible system for animation comes from the artists who worked on the classic film Jurassic Park. Their whimsically-named “Dinosaur Input Device” is described in a 1995 CHI paper [23]. The authors embedded sensors into an armature to control an on-screen puppet. The animators preferred the movement quality of the physically manipulated puppet as compared with computer interpolation-generated movement (and audiences did too – Jurassic Park is frequently cited as one of the best
early examples of an animated character). Such tangible interfaces – called “maquettes” – are relatively common in the film industry; a recent example is the Baby Yoda character from Disney’s The Mandalorian, controlled by four puppeteers with remote controls and one manipulating sticks connected to the arms. Glauser et al. created a system that allows animators to create tangible and modular rigs for controlling digital characters [11], demonstrating improvements in accuracy and time with a posing task. Tangible puppets also enable capture for digital archive purposes [9].

Figure 3: There are many different forms of puppeteering, of which the majority are not as potentially beneficial to incorporate into the animator’s workflow. From left to right, Marionettes like Pinocchio are suspended from strings attached to a hand-held control mechanism. Hand and Rod puppets (e.g. “the Muppets”) are controlled with a hand inside the head opening and rods attached to both hands. Costume puppets like Big Bird, or many of the creatures in Julie Taymor’s The Lion King on Broadway, incorporate the puppeteer’s body into the character. Shadow puppets rely on light and can either be made of cut-outs (as in traditional Indonesian Wayang Kulit [9]), or with hand shapes. Found Object puppetry involves the manipulation of materials such as napkins, paper bags, plastic forks, etc. Nearly any object can become a puppet in this style of puppetry. Such a bricolage practice [42] is uniquely positioned to contribute character design strategies to the world of animation via material jigs that can define, shape, and influence movement qualities of digital puppets.

2.2 Sketching as a Design Practice

Sketching – whether with pen and paper or digital tools – is a design practice that enables a creative practitioner to develop and refine ideas through an iterative process. Sketching – especially early in the design process – should support “rapid, active and contextualized” [26] exploration and creation of a given design space. Creativity Support Tools (CSTs) that support early exploration can provide new paths of least resistance for navigating a design space [31]. Fundamentally, the purpose of a CST is to support and extend the creative practitioner’s relationship with her process, environment and tools. We embrace Dalsgaard’s articulation of Deweyan philosophy, specifically the notion of instruments of inquiry, an understanding of the way the creative process “intertwines” and “co-evolves with” the environment and tools. This elucidates the way a practitioner might leverage tools to augment her own cognition and creative process [6, 17, 33]. These overarching concepts align with Schön’s notion of reflection-in-action [35]. Specifically, our tool creates a path of least resistance towards leveraging the physical world, and allows character designers to include diverse physical objects in their iterative brainstorming process.

Hagbi et al. [15] identify three ‘sketching’ patterns: Sketching then playing (where the sketch is a playing area for future gameplay), sketching as playing (where the purpose of the activity is sketching - it is the main activity), and sketching while playing (where participants alternate between sketching content and manipulating it). Our system embodies the ethos of ’sketching while playing’, but interprets the notion of ’sketching’ more broadly, supporting 3D motion capture rather than on-paper drawing.

2.3 3D Animation Tools and Techniques

Most animation is carried out by following one of two classic animation techniques: key-framing (also called pose-to-pose) where the animator first defines specific poses along the animation trajectory, and then fills in the poses “in-between” these key poses using a process called “in-betweening” or “tweening”. When animation is done digitally, this tweening may be done automatically by the computer, using a technique called interpolation where the computer calculates the path between each pose and moves the relevant component along their respective paths. Interpolation has known issues with producing natural motion: namely the generated movements tend to be uncannily smooth [23].

Another classic animation technique is known as “straight-ahead”. This is the type of animation typically used in claymation or stop motion because it involves proceeding along the animation sequence linearly (rather than skipping ahead to future poses as happens in pose-to-pose). Some animators consider this more intuitive, especially for novice animators. A third technique is referred to as “layered” animation, and involves defining motion for collections of body parts separately, and then collaging the motion
together in a final step. For example, K-Sketch allows the animator to create an animation of a wheel spinning while also moving forward along a path by allowing the animator to record both motions separately, and then automatically suggesting various combinations [7]. Dontcheva et al. specifically designed a system around layered animation for motion capture [8]. Their system allows animators to perform different aspects of a moving character and layer these movements on top of each other to create the final animation. Our system similarly supports recording separate aspects of a digital character then combining them in a separate step. These techniques are complementary and are employed differently based on the animator’s preference and the situation at hand.

As these traditional animation techniques were brought into computer graphics, designers began to create new systems, techniques, and tools for generating and capturing motion. One of the earliest examples of playing back an animation coupled to the motion of an input source was demonstrated in Baeker’s Genesys system [1]. A later computationally mediated motion capture tool includes Calvert et al.’s Life Forms, the front-end of a more general-purpose 3D animation system that allows choreographers to use keyframes and inverse kinematics to create movement sequences [4]. Multi-touch has been shown to lower the barrier to manipulate complex characters [21]. Meador et al. used live motion capture to explore the role of mixed reality in a live dance production [29]. Procedural animation and physic simulation systems, including those built-in to Blender enable automatic generation of rigid-body, particle, and soft-body simulations. While the generated outcomes are often extremely compelling, there is less of a role for a human to design the movement in these procedurally generated animations. Most animation tools tend to support either key-framing [4, 11], straight-ahead [23], or layered [5, 7, 8] animation techniques. While the final result created with any technique should be identical, the tools vary in how they support the ideation process. In this work, we seek to support an embodied, iterative, rapid prototyping process for animators creating character movement.

3 DESIGN MOTIVATION: DRAWING FROM EXPERT CREATIVE PRACTICE

As part of the design process, we engaged with professional creative practitioners in two related fields – animation and puppeteering – about their existing movement design process. We interviewed experts in both fields to develop an understanding of common approaches, techniques, and strategies for engaging in movement design. We identified both commonalities and differences, which allow us to identify fruitful opportunities for cross-pollinating the two fields.

3.1 Interview Procedure and Analysis

To gain an understanding of puppeteering and animation practice, we carried out semi-structured interviews with 2 expert creative practitioners. Interviewees were paid at the rate of $40 an hour. The interview questions were guided by grounding themes of tool use, artifact generation, and personal creative practice, and shaped by the individuals’ background and reflections. Each interview lasted between 2 and 2.5 hours, during which we asked a semi-structured set of interview questions, focusing on their personal creative practice and background. Questions included probes about the creative process such as “Can you walk me through your design process for a particular project?” or “What role does this technique/strategy/approach play in your creative exploration?” or “What are the benefits of technique A in comparison with technique B?”

We then performed thematic analysis on the interview transcripts, iteratively reviewed and analyzed all interview data and discussed all emerging themes [28]. Themes are presented below, categorized into strategies these practitioners use to structure their respective creative processes.

3.2 Participants

Both participants were recruited via professional contacts, and invited to speak with the lead researcher while remotely connected over a video-conferencing system.

Animator – The animator has been working professionally as an animator for over 11 years. She now works for a large animation studio, and has worked with many different companies throughout her career. She works primarily in 3D, and has also explored 2D, stop-motion, and VR animation.

Puppeteer – The puppeteer is an Emmy award-winning performer who has been performing professionally for over 25 years. His work could be categorized as physical comedy, clowning, mime - he excels at physical performance. His primary puppeteering technique is Found Object puppeteering, where everyday materials are manipulated with the hands to create compelling characters. For example, a plastic bag may fold and slightly inflate to become the body of a chicken, with plastic forks for feet.

3.3 Findings

Experts in their respective fields, both our informants have rich practices of movement design. We identified both similarities and differences in their techniques, and identify opportunities for importing expertise from puppeteering into animation, which could shape the design of tools to help scaffold newcomers.

3.3.1 The importance of texture and rhythm. Both the Animator and the Puppeteer are highly attuned to movement qualities such as rhythm and texture as they design characters, develop scenes, and tell stories through their respective mediums.

Animator: I don’t make everything smooth in the scene. I try to include staccato movement to give more rhythm... I use some motions more straight and then some motions more like round shapes.

The Animator was highly attuned to movement qualities like rhythm (e.g., staccato, smooth) and texture (e.g., sharp, round) and how these would shape the final outcome. Similarly, the puppeteer heavily emphasized Laban movement concepts, specifically the four categories sustained, pendular, abrupt, and vibratory. As he’s developing a character or a scene, he keeps these terms top of mind, using them to shape his rehearsal process, and iterate on the design of a character.
**Puppeteer:** The real kicker is the transition between multiple states. So you create a low vibration going into a high pendulum movement. It’s surprising to see that shift of the two different energy levels and that’s what people respond to.

Both experts emphasized the importance of texture and rhythm throughout their design process, highlighting attention to detailed aspects of movement quality as a shared value.

While both experts highly valued nuanced movement qualities, they had different relationships to the process of generating such movement. The puppeteer’s Found Object puppetry technique emphasizes the use of physical materials to create characters. A paper bag can be expanded with the hands, then crumpled, then re-inflated to convey breath. A piece of foam or a scrap of fabric might be stretched out to communicate gravity and weight. The puppeteer articulated the ways in which these materials shape his exploration of characters:

**Puppeteer:** [The character design] all depends on the material that you’re using... you start playing with it and then that’s where you make the discoveries.

The materiality inherent in his puppeteering practice guides him throughout his design process and helps him generate new movement qualities. In contrast, the Animator’s digital process has a more limited relationship to materiality. She discussed the particular challenge she would face if asked to design an abstract, non-humanoid, non-animal character:

**Animator:** If I had a character that was the shape of water I would just try to [create] motion in general, I guess, rather than looking for a reference... thank God I have never had to do that – I probably would have a hard time.

In contrast, the puppeteer was able to rely on exploration with tangible materials to aid his ideation as he generates motion ideas for such abstract characters. In general, the physical objects played a major role in the Puppeteer’s design process, the materials directly influencing movement:

**Puppeteer:** [The way we move] becomes unconscious, becomes habit, becomes muscle memory, becomes us. [Using a puppet provides] a sense of allowing your body a chance – and your mind a chance – to shift its perspective. You add new limitations onto yourself and create new avenues for yourself.

He articulated the value of a physical object: it provides additional movement constraints, suggests new movement qualities because of those constraints, and provides some “separation from oneself” throughout the creative process. While tangible “puppets” – called maquettes – were frequently used in the early days of animation [23], they are less frequently used now, and the Animator had not used them in her 3D animation projects. Her design process centers around digital characters, which have no analogous qualities.

### 3.3.2 Observation and attention to detail

The Animator also described the “misconception” that animators often feel early in their career, when they incorrectly believe they can simply generate natural movement without first engaging in focused observation:

**Animator:** Even right now, you talking to me – you think you know what you’re doing, but your shoulder is moving and your head is nodding and you don’t notice the frequency at which it’s nodding. We think we do, but we don’t. You need help to go to the source of the movement and seek the truth of the animation, which is recreating life.

Both practitioners articulated strong attention to the way subtle and nuanced movement design influences the final character.

#### 3.3.3 Summary

In summary, movement qualities are very important to character design in both contexts, and the Puppeteer finds that incorporating physical materials into his character design process is an extremely effective method for positively influencing the movements and characters he generates, especially for abstract characters. As we reflected on these interviews, we generated the following questions, which this paper seeks to address: *Would an animator get similar benefits from incorporating materials into their design process? In what ways might the Found Object puppeteering technique positively influence an animator’s style, or exploration process? How might we design a computational system that allows such material explorations? Would a new or augmented animation tool fit into an animator’s existing workflow?* In this work, we seek to answer how we might design a computational system which incorporates the material exploration that the Puppeteer found so essential.

We also discussed the role of computational tools in animation with the Animator, who repeatedly emphasized the importance of developing skills in the “art form of animation”, and of not getting hung up on the specific animation software in use. She discussed the way novice animators are sometimes undermined as they begin their journey to learn animation:

**Animator:** We all say “animation is recreating life” but then the first thing that new animators do is get in front of a computer and try to learn software – they forget that life aspect.

We interpret this as a call to the importance of observation of the physical world in animation. The combination of the Puppeteer’s physical materials – or jigs, because they helpfully constrain movement – and the Animator’s desire for novice animators to develop an eye for movement suggests the potential value in incorporating physical objects into the animation process.

### 4 PUPPETJIG

Throughout the formative interviews, we were struck by the role that materials played in the Puppeteer’s process. While both experts discussed the importance of varied movement qualities, we wondered how much the digital “material” of 3D animation influenced the final outcome for those using 3D animation tools. The core idea behind PuppetJig is finding a way to incorporate the same types of physical materials used by the Puppeteer into digital animation workflows in order to enhance sensitivity and attention to the physical movement qualities valued by the Animator.

The Puppeteer described his materials as helpfully constraining his movements, much like the way that jigs and fixtures support woodworkers by providing selective constraints to motion. While jigs in woodworking are typically solid and hold cutting materials securely in place, and the Puppeteer used soft or flexible materials such as a napkin or a jacket, the core idea of an external tool that helpfully limits movement remains the same. We therefore also
Animation Tool (Blender)
Tangible Controllers
Woodstock '18, June 03–05, 2018, Woodstock, NY
Trovato and Tobin, et al.

When partially or mostly occluded, and provide a more robust con-
nection between the digital and physical worlds. The HTC Vive
controllers also provide centimetre-level accurate tracking, thereby
satisfying the first requirement especially for an early sketching
process (see Section 3).

4.1 PuppetJig Technical Architecture
PuppetJig is a system that enables animators to manipulate a digi-
tal character while also interacting with physical material jigs, or
otherwise taking advantage of features in the physical world (e.g.,
gravity, momentum). It shares important features with other motion
capture systems: both our system and other motion capture systems
allow animators to capture performed body movement. However,
there are important distinctions: our system does not require a
full-body tracking outfit, instead the only tracked components are
the controllers. This makes tracked movement simpler to generate
and allows for quicker transitions between performing and editing,
key to any creative process [37]. Our system is designed to support
rapid, early ideation in the pre-production character design process
where designs are meant to stimulate conversation; any generated
character movement is not meant become part of the final produc-
tion. In this way, the generated movement can be understood as an
early sketch, and is not meant to be highly polished or complete.

The system consists of three components (see Figure 4):

- The Animation Tool – this provides access to the rig and 3D
  model. The Animation Tool is Blender, an open-source 2D/3D
  content creation tool, running on a desktop computer. The model
  can be adjusted with either the keyboard and mouse, or the tangible
  controllers. Blender also provides basic animation functionality such
  as keyframe recording, rigging controls, inverse kinematics, etc.
- The Tangible Controllers – Two HTC Vive controllers pro-
  vide centimetre-level accurate position tracking, and act as a
  translator between the physical world and the digital one. Us-
  ing a custom script and the opensource library PyOpenVR, we
  stream location data from the controllers into Blender, where they
  change the location and orientation of a selected character.
- Material Jigs – based on the Puppeteer’s described technique,
  we collected a variety of physical objects for animators to
  use as jigs during their animation process, including weights,
  a stretchy band, different kinds of fabric, and a plastic bar
  (see Figure 4).

To use the system, an animator first creates or downloads a 3D
rig (a standard first step in any animation). Next, the animator opens
the custom UI, and connects any single bone in the armature to
each controller. Now the controller movement is bound to the 3D
rig, which allows the animator to control the digital character with
physical movements in the real world. Optionally, the animator can
use the material jigs to influence, perturb, inspire, and shape their
movements, similar to the way the Puppeteer used materials in his
design process (see Section 3).

5 PUPPETJIG EVALUATION
Evaluating novel toolkits is notoriously difficult [32], sometimes
– as in the case of usability assessments – even considered harm-
ful [13]. Beyond usability evaluations, there are a variety of strate-
gies that can be used to assess toolkit effectiveness [24]. Like many
novel toolkits, PuppetJig requires time and effort to build familiar-
ity and incorporate into a workflow, meaning such a tool would
not typically be considered a good candidate for lab usability stud-
ies [13, 25]. Instead, the focus of our user study was not on usability,
but rather on understanding how incorporating physical elements
as a first-class design material alters the design decisions taken by
practitioners even during a first encounter. We therefore invited
two novice animators in to experience the tool.

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Figure 4: PuppetJig consists of 1) the animation tool Blender
running on a desktop computer, 2) HTC Vive controllers,
allowing tangible manipulation of the digital model, and
3) material “jigs” for the designer to manipulate during
ideation. Note that no headset is required: the digital pup-
et is viewable through the desktop computer monitor.

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Notes:

- Version 2.93, https://www.blender.org/
- The URL of the open-source software will be provided after acceptance.
- https://github.com/cmbruns/pyopenvr
5.1 Procedure

Both participants visited our lab for a 1.5 hour workshop and was compensated $40. Each session consisted of 1) interview on background and personal design practice, 2) a warm-up tutorial 3) a series of exploratory design tasks following a think-out-loud protocol and 4) a post-study interview. Participants were introduced to the tangible controllers first, while learning to control a single bone (see the simple abstract model in Figure 5a), and learning how to move the controller in physical space to control the digital character. Next, they were introduced to the notion of the physical jigs: “When puppeteers design a new character, they often play with different materials as they’re exploring. We’ve provided these different materials for you to use as you think about the character you are designing. Interacting with a physical material might influence how the final movement looks”. After participants had experienced the simple abstract character and the jigs, participants proceeded to the exploratory design task. Participants were instructed to iterate on a new character design, and to create two 5-10 second scenes (one with low energy and one with high energy) where an audience would learn about that character through the way that they move. Both participants chose to design their movement using the complex abstract character (see Figure 5c). During the study, participants chose which found object material jig(s) to use while holding the controllers and manipulating the on-screen digital character.

We recorded and transcribed what each participant said while thinking aloud as they experimented with the tool for the first time. We then performed a thematic analysis on their transcribed quotes, and synthesized our findings into themes. This study design allowed us to observe the way the tool affects the design process on a first encounter, with designers who are new to the system.

5.1.1 Participants. The study was conducted with two novice designers (avg. 29 years of age, 2 female). Participants were recruited from university mailing lists in Art, Architecture, Design, and Computer Science. Prior experience with 3D modeling was self-reported in a preliminary survey; we purposefully recruited participants with varying levels of expertise in animation: one participant reported intermediate experience with animation, and the other participant had no prior experience. Since we have a small number of participants, we describe them in more detail to further contextualize their responses:

P1 - P1 is learning Blender, and has intermediate experience - she has used it for several ongoing animation projects. Her background is in product design, and while she has primarily worked on websites up until now, she is very interested in tangible experience design.

P2 - P2 has a background in psychology, and has zero prior experience with animation, or animation tools. She is a film buff, and considers herself well-versed in animated movies as an artifact, but has never created animation of her own.

5.2 PuppetJig Study Results

Even in a brief workshop-style experience with limited exposure to the tool and this method of working with digital animation, users readily engaged in unique movement-generating behaviour. See Figure 1, right for examples of jig exploration our participants engaged in.

5.2.1 Access to Jigs Influenced Design Process and Outcome. P1, who has some prior experience designing animation in Blender, compared her experience using PuppetJig with Blender. In particular, when designing a “low energy” experience for her character, she experimented with weights as jigs. P1 connected the feeling of heaviness with the increased weight of the emotional message she was hoping to convey:

Designer: Low energy means I have a lot buried in my shoulder and in my mind. That’s how it feels - your body is very heavy. I just want to see what that would do to my hand and my character if there’s actually weight on it.

While she was familiar with Blender’s built-in parameter to increase the weight of a character’s body part, the experience of physically manipulating weights as she performed the digital puppet’s movements impacted her design experience. She described the way she might update the “weight” of an object in Blender, and compared that with the experience of holding varying amounts of weights while animating with PuppetJig, which she described as “the real version” of such a design choice. The tool created an embodied experience with weight:

Designer: [This tool] is a way to embody when I change the metrics or parameters in the software. Without this tool, it was just a click from the mouse and it doesn’t feel that real. I thought it was real before, but now, with this, I feel like this is great – way more real!

P2 also engaged in extremely physical exploration of the tool, moving around the room, waving her arms in the air, bouncing the...
controller on the fabric, and swinging the controllers around. She felt that the material jigs anthropomorphized the movement that the tool helped her create:

**Novice**: Using this free-flowing and bouncy material almost personifies this figure in a way. If I use it just with my hand it’s more controlled but this makes [the movement] more unpredictable.

P2 found this controlled unpredictability an appealing and compelling addition to her character during the creation process.

5.2.2 **Tangible Control System Enabled Physical Explorations.**

In addition to using the jigs to modify her character’s movement qualities, P1 experimented with using the tangible controllers to incorporate gravity and momentum into the digital character movement. She tied the controller to a piece of stretchy fabric, and let it drop as an expression of despair:

**Designer**: I like how it just hangs here. Because when you drop everything you’re like “I don’t have any hope - I’m so sad, no, no.”

Similarly, P2 described a compelling sense of less control when using the material jigs, which she felt improved the movement:

**Novice**: I really like using these [materials] because you have more range and it comes to life more. It’s just less structured.

Both participants felt the material jigs positively affected their overall design experience.

6 **DISCUSSION**

By incorporating the material jigs into the design process, our participants developed their sense awareness [10] of the physical world. That is, in addition to choosing jigs to influence, shape, refine, or limit their movement, participants also began to experiment with the way other physical elements such as gravity and momentum could influence their character’s motion design. This increased sensitivity to physical effects and the way such effects could influence their design resonates with the Animator’s goal of encouraging novice animators to “recreate life”. In addition to material jigs, future tools could explore the use of software jigs as have been introduced in woodworking [39]. Additionally, digital jigs such as a gyroscope, a buzzer, or an electromagnet could further shape the motion design experience, and may influence the puppeteer’s analog methods.

While novice animators wouldn’t be expected to generate polished animations during a first encounter with any novel animation tool, participants did deeply engage with the design process, and articulated perspectives on movement design that align with the goals of both the Animator and the Puppeteer. Even with the simple abstract model (see Figure 5), participants immediately jumped up from the table, and used the provided materials to investigate different movement qualities. Participants did tend to anthropomorphize this simple geometric shape, probably a demonstration of the classic Heider and Simmel Illusion, where observers ascribe personality to moving geometric shapes [16]. As a next step, we hope to invite in participants who are more familiar with Blender, as well as expert animators to try the techniques and assess how such influences might fit into the professional’s workflow.

Our findings position our tool as a low-fidelity, early prototype “sketching” style interface ideal for quickly generating a multiple options for movement, or for exploring a character’s movement style. We imagine such tools used for exploratory animation work in tandem with established animation pipelines, which are already highly effective for precise control.

7 **LIMITATIONS AND FUTURE WORK**

While this system requires the fairly extensive HTC Vive setup to use, we hope to inspire future designers to think about smaller, even more accessible tools that support the capturing, saving, collecting, or collaging of motion. Similar to the way many music artists keep collections of “found” audio clips (such as a dentist’s drill, or the beep of a traffic light notification), we envision a broader engagement with movement as a design material. For example, imagine being able to quickly design the wave your Bitmoji does in a conversation with a friend. We imagine tools that support increased engagement with movement across many contexts: animation, application design, social media.

8 **CONCLUSION**

We have taken the first steps towards investigating the benefits of incorporating material objects as jigs into the animator’s workflow. Our initial user study is an exploratory probe into the impact found Object puppeteering techniques can have on novice animators as they engage in movement sketching. We end by celebrating the benefits of drawing on expertise from two separate but related fields, each with complimentary approaches.

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