W.O.U.S.: Widgets of Unusual Size

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ABSTRACT

Recent work in tangible interfaces, including widget sets like .NET Gadgeteer and Phidgets, has enabled prototyping of rich physical interaction at a handheld or tabletop scale. But it remains unclear how participants respond to physical widgets at larger scales. What kinds of interaction would larger widgets enable, and what kinds of systems—if any—can or should be built with them? We built unusually-sized widgets, or “mega-widgets” in order to explore this territory. We present the results of two iterations of building mega-widgets and accompanying user studies designed to help understand participants’ reactions to mega-widgets and probe possible applications. Responses indicated, among other things, a correlation between widget size and the perceived size or importance of what it might control. Mega-widgets were also perceived as increasing the precision of user input control and providing a fun and playful element. We hope that knowledge gained from this exploratory work can help lay groundwork for further exploration of widgets at larger scales.

INTRODUCTION

Over the past two decades, much work has considered how to build tangible interfaces in which physical widgets, rather than virtual widgets in a GUI, control a system. To that end, many collections of physical widgets have been built and discussed, such as Phidgets [5], .NET Gadgeteer [7], Sauron [16], and others [18, 6, 19]. However, in each case, the physical widgets work at the scale of a finger: a knob is sized to be grasped and rotated by fingers, as are other controls like buttons and sliders.

It remains unclear how people react to and imagine using tangible widgets at larger scales ranging from a handspan to an armspan. We call widgets at this scale “mega-widgets”. Mega-widgets are commonly used in a small number of applications such as automobiles, industrial control panels and children’s playgrounds. See, for example, controls for a ship in Figure 1.

While Fitts’s law is widely used and understood, and much research has explored the effects of widget size in GUI interfaces, large *physical* widgets have not been adequately

explored within an HCI context, and pose a number of interesting questions such as: how might mega-widgets be used? Are they useful or merely impractical? How might participants respond to mega-widgets? Do mega-widgets provide affordances which may differentiate them from regular-sized widgets? What types of new interactions might they enable? In what situations might mega-widgets make sense? How can mega-widgets be constructed?

We anticipate that knowing how people react to and imagine using mega-widgets may be useful within the tangible user interface community because it allows people designing and implementing new systems to work from a deeper understanding of how widget size impacts tangible interface design.

In order to begin understanding the response created by mega-widgets and exploring their possible applications, we conducted two exploratory user studies. In the first, we sought to understand participants’ initial reactions to mega-widgets and their impressions about what mega-widgets might be used for. In the second, we further refined our understanding of themes uncovered in the first study and explored potential applications for mega-widgets on a deeper level.

In the initial study, we fabricated mega-widgets and invited people to interact with them, and then to share with us their reactions and imagine possible uses for mega-widgets. We carried out an analysis of user responses by clustering their comments using “word embeddings” [15]. We found themes related to novelty, as might be expected, as well as others suggesting a correlation in the size of the physical control and the size of the phenomenon being controlled, and play. The applications suggested by participants included both serious and playful, and emerging themes of interest included play and visibility, among others.

Following up on the initial study, a second study was conducted using another set of mega-widgets with designs based on insights gained in the first study. This study aimed to further refine our understanding of themes identified in the first study and explore possible applications for mega-widgets. In this study, participants were invited to interact with mega-widgets and then pair applications with a specific widget type and size. We interviewed each participant asking them why they had made certain pairings, and conducted thematic analysis of participants’ answers. Themes in this study had some overlap with those of the first study, while new themes also emerged, such as mega-widgets increasing the precision with which something can be controlled.

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TEI '18, March 18–21, 2018, Stockholm, Sweden

© 2018 ACM. ISBN 978-1-4503-5568-1/18/03...\$15.00

DOI: <https://doi.org/10.1145/3173225.3173246>

Figure 1. A ship's steering wheel is a mega-widget sized knob larger than a handspan but smaller than an arm span. (Image by dreamstime.com contributor Eugen Sergeev.)

Through two exploratory studies involving two sets of mega-widgets, we have begun to explore unusually-sized physical widgets, individuals' reactions to them, and their possible uses. We hope this paper and the studies it details will be effective groundwork for further exploration in this area.

The primary contributions of this paper are:

- a definition of the “mega” scale for physical widgets,
- exploration of how people react to and imagine using mega-widgets, and
- directions for future exploration of unusually-sized widgets

RELATED WORK

Widget Sets

Much prior work has been done in building and testing widget sets at “normal” scale for use with fingers. In this paper, we will refer to these as “finger-sized” widgets. Phidgets [5], an early pioneering work in this area, lays out the underlying motivations and conceptual framework behind such efforts. Namely, physical widgets aim to do for physical devices and interfaces what software widgets do for on-screen user interfaces: provide modularity, hide of implementation details, and simplify design and implementation.

Since Phidgets was published, many others have created physical widget sets and methods of adding them into physical devices. .NET Gadgeteer [19] combined “solder-less modular electronic hardware; object-oriented managed software libraries accessed using a high-level programming language and established development environment; and 3D design and construction tools” with the goal of providing flexibility, accessibility, and versatility.

Still other work explores physical widgets in the context of a physical housing. This includes forming the shape of housing using cardboard [8], foam [12, 1], and clay [9] or other sculpting media [17]. We have opted to leave exploration of integrating mega-widgets with a physical housing or other context for future work.

Figure 2. An example of a mega-widget intended for accessibility purposes.

Large Controls

Controls of larger sizes occur in some real-world situations, such as the aforementioned ship controls in Figure 1. In the past, one motivation for mega-widget scale controls was due to controls being connected to mechanical linkages. Although most modern controls use hydraulic or electronic linkages rather than mechanical, many such controls retain their larger size. This is presumably for other reasons such as to convey importance, to enable precise control by providing a larger range of motion, or to allow use of the control from a wide range of positions.

In other applications, large size is used for a fun and playful effect, such as in the construction of a giant-sized Nintendo controller¹ and remote control². This type of application of size seems to recall childhood, where the entire world seems larger and curiosity abounds.

Accessibility for those with disabilities is also often accomplished via size, such as in the mega-widget-sized door open panel in 2. In this case, the larger size eases use for individuals for whom small buttons might be difficult to reach or press. While accessibility is an important application area for mega-widgets, we leave accessibility to future work.

BUILDING MEGAWIDGETS

We begin with a brief discussion of the “handspan to armspan” scale previously defined. For our purposes, a handspan is the distance between the tip of the little finger to the tip of the thumb when the fingers are fully extended. An armspan is the distance between middle finger tip to middle finger tip

¹<http://www.popsoci.com/diy/article/2011-12/you-built-what-worlds-largest-videogame-controller>

²<http://www.guinnessworldrecords.com/news/2016/1/video-indian-brothers-build-14-ft-tv-remote-control-and-prove-it-actually-works-411614>

Figure 3. Widgets used in the first study were intended to represent a blank slate on which participants could project their thoughts and reactions.

when the arms are extended horizontally. We chose these as lower and upper bounds because they are sizes large enough that multiple hands are likely required for operation but not so large that a user will have to take a step during operation.

3D printing has made fabrication at the scale of normal-sized widgets quick, easy, and flexible. 3D printing is not yet easily applied to problem of fabricating a mega-widget. Thus fabrication of objects at the scale covered by mega-widgets requires application of more traditional forms of craftsmanship.

In order to make mega-widget construction simpler and more efficient, we have broken construction of an individual mega-widget into four separate modules: frame, mechanism, sensor and cap. This modularity allows for greater flexibility and ease in design and construction.

The *frame*, as its name suggests, is the housing or base which holds the other parts of the mega-widget. We used slotted aluminum bars from 80/20 Inc³ to construct frames. This material was useful for this application as it is sturdy, tools are available for working with it, and the slots provided flexibility in assembly and expansion points for affixing mechanisms.

The *sensor* bridges the gap between physical motion and digital signals. We used three kinds of sensors which vary depending on the mega-widget type. For sliders and knobs we used ArUco (fiducial) markers as presented by Garrido-Jurado [4] in a camera system. For buttons, we used a packaged leaf button.

The *mechanism* in a mega-widget connects the frame to the cap. The mechanism allows the cap to move and provides haptic feedback. For sliders, the mechanism is a base which slides in the 80/20 slots. For knobs, the mechanism is a turntable bearing with one side anchored to the frame and the other side attached to the cap. The button mechanism is a spring system which allows the button to be depressed. To provide haptic feedback, we added pieces of felt to mechanisms for both sliders and knobs, thus providing friction-based resistance to the user's motion.

The *cap* is the object which the user sees and grasps, moves, or touches to interact with the mega-widget. The cap can be replaced without modifying the mechanism or sensor. We fabricated caps from foam and plywood but a wide range of cap

fabrication methods and materials are possible. Fabrication of the cap involves craftsmanship in the creation of a tangible experience.

We fabricated two sets mega-widgets with different caps and used one set in each of the user studies described below. The first set of caps, shown in Figure 3, were intended to represent a blank canvas on which participants could project their thoughts about mega-widgets. Caps were shaped like scaled-up versions of finger-size widgets and painted white. For example, the knurls on a finger-sized knob give the fingers grip as they grasp and spin the knob. Those knurls scaled up to mega-widget size become larger than a finger or even a hand.

The second set of caps, shown in Figure 5 used color and shape to make the purpose and position of the widget more obvious. The caps used white markings on a grey background to indicate position and to prompt movement. We shaped the caps to make them graspable and usable. On the large knob cap, for example, graspable ridges on the edge of the cap invite the user to grab and turn the knob. This was a departure in design from the first set of mega-widgets, which were simply mega-scale versions of regular widgets.

We call mega-widgets “large,” “very large,” or “enormous” depending on their size. A *large* mega-widget is about the size of a handspan. A *very large* mega-widget is in between the sizes of a handspan and armspan. The *enormous* widgets are the size of an armspan. All widgets in Figure 3 are *enormous*, and all three sizes are depicted in Figure 5.

USER STUDIES

We conducted two exploratory user studies in order to gain an understanding of how participants respond to physical widgets at unusual sizes and to lay a foundation for future work.

In the first study, we sought to understand initial reactions by presenting participants with mega-widgets, allowing them to interact with them, and asking them to describe their reactions to them and to give us their ideas for possible uses.

Based on themes derived from responses and uses suggested by participants in the first study, we conducted a second study to explore participants' feelings about mega-widgets as it relates to their application to different usage scenarios.

³<https://www.8020.net/>

awkward unintuitive interesting fun
playplace huge overbearing fun natural
intuitive clear easy large restricted
important constructible fun exploring
curious playground fun easy clear
curiosity smooth instinctive cool
interesting interesting ginormous
useless why youthful discovery fun new
large light mindless resistant

Figure 4. The forty words generated when 10 participants were each asked to give 4 words to describe the mega-widgets shown in Figure 3. We used a clustering algorithm on word embeddings of these words to identify themes.

Study 1: Gauging Reactions and Imagining Applications

Assuming that widgets at “mega” scale would be a new experience for most individuals, our first study was aimed at understanding initial reactions. In order to do this, we invited 10 people (5 male, 5 female) to interact with mega-scale button, slider, and knob models shown in Figure 3. Interactions largely involved exploring the mega-widgets’ size, shape, and range of motion by touching and moving them. Participants were recruited via convenience sampling on a college campus and were college-aged. Majors reported by participants were Computer Science, Economics (pre-med), Chemical Engineering, Math, Chemistry, Family Home and Social Sciences, Accounting, and Early Childhood Development.

Four Word Descriptions

In an effort to capture visceral reactions, we asked each participant to give us 4 words to describe their reaction to mega-widgets. These words are shown in Figure 4. This list includes opposites, like “unintuitive” vs. “intuitive” and “awkward” vs. “natural”. It also contains words which require interpretation like “youthful” and “cool”. We asked for one-word responses with an algorithmic approach in mind, which we hoped would be a fast and simple method for analysis without introducing bias. This approach is described below.

The understanding of words in context is a fundamental objective of natural language processing (NLP)[13]. Common techniques in NLP, such as latent semantic analysis and the related information retrieval technique, latent semantic indexing [2], assume that “a word is characterized by the company it keeps” [3], and have been in use for some time.

In analyzing the data from this study, we have chosen to use a more recent, faster implementation of the “Word Embedding” idea, known as word2vec[15]. Embedding maps words with similar meaning to points that are near each other in the embedding space. Arithmetic operations in the word embedding space often correspond to their meaning the training corpus. For example, in an embedding space based on Wikipedia articles, the embedding of “king” minus “man” plus “woman” is approximately the embedding for “queen.” We used a 300 dimensional embedding space trained on English Wikipedia articles⁴.

⁴As found at <https://github.com/turbomaze/word2vecjson>

Clustering Results

Using this embedding, we evaluated each of the words given by our study participants. Given the embedding values for each word we clustered the words using k-means to find clusters in the embedding space⁵.

We employed cosine similarity as the distance metric for k-means clustering. Given a and b which are the semantic embeddings of two words, the cosine similarity between the embeddings is:

$$\text{similarly}(a, b) = \frac{\sum_i a_i b_i}{\sqrt{\sum_i a_i^2} \sqrt{\sum_i b_i^2}}$$

where i ranges over the dimensions of the embedding space.

Using these methods, we arrived at 5 clusters of words. In our testing, different numbers of clusters yielded less productive results. Further exploration of this approach in contrast to techniques such as open coding is warranted but outside the scope of this paper. Our approach proved very useful in our early exploratory study.

The clusters we identified are as follows, using the 3 words nearest the centroid of each as descriptors:

Fun, Enjoyable, Easy—This cluster expresses one of the sentiments that was widely discussed among researchers in the initial stages of this project: having such large widgets seems to evoke a fun and playful feeling.

Clear, Visible, Obvious—This may indicate that participants thought the purpose of the widgets or what type of controls they were was clear, or it may be related to the fact that it is easy for others to see widget operation from a distance.

Interesting, Curious, Intriguing—This cluster seems fairly obvious given the novel nature of mega-widgets, and probably captures the novelty effect as it seems that this is a common reaction when participants see something new and interesting.

Large, Huge, Massive—This is probably a reaction to the physical size of the mega-widgets, although the results of the second study seem to suggest that it may also relate to participant perceptions about the size of things that might be controlled by mega-widgets.

Mindless, Useless, Brainless—This may be an indication that the mega-widgets are simple and easy to use, or it may be that participants felt they were unnecessarily large (hence the word “useless”). It may also reflect the fact that the mega-widgets were not connected to any actual functionality for this study.

Applications

We also asked participants to imagine applications of the mega-widgets. We did not use word embeddings to identify themes in these responses because we were seeking more thoughtful discussion of application ideas rather than initial gut reactions, as facilitated by the one-word responses.

We employed a thematic analysis approach in which multiple study team members performed open-coding on participant

⁵<http://scikit-learn.org/stable/modules/generated/sklearn.cluster.KMeans.html>

responses and subsequently discussed findings, coming to a shared agreement on points of disagreement and deriving major themes from frequently occurring code points. Four significant themes emerged from responses:

Misunderstood Shape Cues—6 of 10 participants made comments which seemed to indicate that they misunderstood the cues intended by the shape of the caps. For example, participant P5 thought the dip in the slider cap looked like “it would fit a leg.” Two participants, P1 and P7, thought the button cap should twist and three participants, P1, P8 and P10, thought the knob cap looked like a gear that might be used in a gear system.

Big Things Need Big Widgets—Four participants (P3, P4, P6 and P9) said that big widgets must control big or important things. Participant P4 said “these are big devices so they should control big things.” Big applications of mega-widgets included controlling the sky (P9), turning on the sun (P9), emergencies (P3), operating stadium lights (P6) and operating a theater curtain (P6).

Play—6 of 10 participants suggested applications or made comments related to play. Participant P5 said “I feel like I’m on a playground” while interacting with the mega-widgets. Applications included television game shows (P6 and P8) and playgrounds (P2, P5, and P9). Participant P7 recalled amusement parks such as LEGO Land and Disneyland.

Visibility—Three participants (P1, P2 and P4) noted that the value of mega-widgets was that people could easily see the widget move from a distance. Participant P2 said the mega-widget “shows off what you are doing.” While we found this theme in only 3 responses, we considered it significant insofar as it describes a feature of mega-widgets not found in finger size widgets. This theme may also relate to the “clear, visible, obvious” theme from the word embedding analysis.

Study 2: Matching with Applications

In the second study, we invited 20 people (7 female, 13 male) to pair widgets of different types and sizes to applications. As with the first study, convenience sampling was used in a campus setting, and participants were of college age. There was no overlap in participants between the two studies.

The goal of this study was to further explore participants’ responses to mega-widgets by asking them to pair mega-widgets with possible applications, both realistic and whimsical. We opted for pairing with imaginary applications rather than actually building systems for participants to control because it allowed for greater breadth, as construction of systems using mega-widgets would have limited a study with real-life applications to only a few modest use-cases. The full list of applications used in the second study appears in Table 1.

The 20 applications were imagined by the research team based on three of the themes identified in the first study: *Big Things Need Big Widgets*, *Play*, and *Visibility*. Our intent was to measure pairings between widgets and applications in a way that would help us further understand these themes. We also expected that other themes might emerge.

Roller Coaster Sprayer	Lights: Bedroom
Lights: Concert/Club	Lights: City
Pong	Temperature: Room
Temperature: Dorm	Temperature: Skyscraper
Emergency/Alarm Button	Tune Radio
Interest Rate: Branch	Interest Rate: Bank
Interest Rate: Federal	Dam Water Flow
Admissions GPA	Class Grade Curve
Spice Level	Car Vending Machine: Model
Car Vending Machine: Color	Car Vending Machine: Buy

Table 1. List of possible applications used in the second user study. “Spice Level” refers to a control to set how mild or spicy one would like their food to be at a restaurant. “Pong” refers to the classic videogame. “Car Vending Machine” is an imaginary vending machine that vends actual full-size cars.

The fourth theme in the first study of mega-widget applications, *misunderstood shape cues*, was addressed in the second study by redesigning caps to make their use more clear. This was done using color to represent position and adding appropriately-sized physical elements such as graspable ridges.

Applications were chosen which explored each of the themes, including some specifically designed to be playful (*Roller Coaster Sprayer*, *Pong*), some where visibility might be important (*Interest Rate*, *Spice Level*, *Alarm Button*, *Temperature*), and multiple sizes of some, intended to determine how strong the correlation between mega-widgets and the size of what they should control might be in participants’ minds (*Interest Rate*, *Temperature*, *Lights*).

We also included baseline applications for which people already use finger-size widgets. The purpose of the baseline was to determine whether or not the presence of mega-widgets influenced people to pick them regardless of the application.

The mega-widgets shown in Figure 5 were used in the study along with finger-size widgets as a control. The finger size widgets were small devices constructed from commodity button, slider and knob parts with caps that had the same shape and color scheme as those in Figure 5.

During the study, participants were given a packet with one sheet of paper for each application. Each sheet included the name of the application and a description, such as “Dam Water Flow: Imagine controlling the flow of water through a dam.” A table of widget images appeared at the bottom of each page showing photographs for each widget type and size. Participants were then introduced to a room containing the mega-widgets and regular-sized widgets pictured in the table of images. Participants interacted with the mega-widgets by pushing buttons, sliding sliders, and turning knobs. Participants circled the photograph of the widget type and size they paired with each application. Some participants interacted with widgets mainly at first prior to making assignments, others interacted to one extent or another during the process of making assignments, and still others hardly interacted with widgets at all beyond brief time spent looking them over prior to making assignments.

Figure 5. Widgets used in the second user study were designed based on insights gained in the first study. White markings on sliders indicate directions of travel and markings on the knob indicate position. Widget caps are shaped to invite gasping and motion.

The Pairings

The chart in Figure 6 summarizes the pairings of widget size and application for 20 participants and 20 applications. The six bars which are shorter reflect where participants missed making a pairing for that application. The columns in Figure 6 are sorted by the sum of very large and enormous widgets.

We expected that applications with large physical components (dam control, car vending machine) and important applications (including the Federal interest rate, city lights, skyscraper temperature) would be paired with large widgets. For the most part, this was true. However, the class grade curve, which affects a relatively large number of people, was paired with finger-size widgets 14 of 20 times and the alarm, which is fairly important and could also benefit from increased visibility was paired with large and finger-size widgets all but once.

We also expected the two playful applications (roller coaster water sprayer and pong) to be paired with large widgets. The roller coaster sprayer was paired with very large or enormous widgets 10 times and with finger-size widgets only 3 times, as expected. But the pong game was paired with finger-size widgets 9 times and very large or enormous widgets only twice. It may be that previous pong or videogame experience with finger-sized widgets caused participants to lean that direction. It may also be that the increased energy expended and distance to be covered using a mega-widget dissuaded participants from choosing them in this case.

We expected the baseline applications (room temperature, bedroom lights and radio dial) to be paired with finger-size widgets as they are in normal usage. Room temperature and bedroom light controls were paired with the usual finger-size controls 37 of 39 times. The radio controls were paired with finger-size widgets 14 of 19 times.

Rationale for Pairings

Before the study we selected 8 applications of interest to discuss in more detail with participants. To avoid interview fatigue, each participant was asked about 4 of the 8. The Latin squares method was used to assign which participants to ask about which applications. Applications which were discussed were selected to cover a broad swath of the concepts which were encapsulated by the overall application list. The applications selected were: *Lights: City, Temperature: Skyscraper, Temperature: Dorm, Interest Rate: Federal, Car Vending Machine: Model, Roller Coaster Sprayer, Class Grade Curve,*

and *Dam Water Flow*. For each pairing we asked two questions: Why did you pair this application with that widget? Why did you not pick a different size? We asked the questions whether the participant had selected a mega-widget or a finger-sized widget for the given application. Interview notes were analyzed using the same thematic analysis approach as the previous study of mega-widget applications.

We found three dominant and two secondary themes. The three dominant themes were precision, size and importance and a sense that some of the widgets were too big. The two other themes which appeared less frequently were games and accidentally bumping the widget to change the value.

Precision—Participants paired applications with mega-widgets in order to give more precise control in the application. 23 pairings involving mega-widgets were justified in terms of precision. For example, P6-2 selected a very large knob for “Temperature: Dorm” because it is “more detailed” and “gives better control.” Participant P4-2 selected a large knob for “Temperature: Skyscraper” because it was “bigger for fine tuning.”

Size and importance—As in the first study, participants made a connection between physical size or application importance and the size of the widget. 21 pairings of mega-widgets were justified based on the relationship between size and importance. In some cases, particularly for “Dam Water Flow”, participants picked a mega-widget for an application in order to gain mechanical advantage. For example, P11-2 picked the enormous knob for the dam flow control application because “there’s more power behind it.”

In other cases, participants picked a mega-widget because the underlying application was important. P7-2 picked the large slider for the city light application because “for something as big as a city use something industrial.” Similarly, P15-2 picked the enormous slider for city lights control because “a lot more people care” and “it matters more.”

Participants picked mega-widgets for applications based on the importance of the application even when the application had no physical component. P14-2 picked the enormous slider for “Federal Interest Rate” because “the largest scale problem should have the largest slider possible” and P16-2 picked the large knob for the class grade curve because it was “slightly bigger to account for the importance level” of the application.

Figure 6. Pairings of widgets with applications generated by 20 people for 20 applications. Columns are sorted by the sum of very large and enormous widgets with “enormous” widgets at the top of each stacked bar and finger-size widgets at the bottom. (One participant did not make a pairing for six applications.)

Some widgets were too big—This was a reason *not* to pick a larger mega-widget for an application and was given as a justification 21 times. Larger widgets were not selected because they would be a “hassle” (P4-2), “impractical” (P19-2), “obnoxious” (P16-2) or “intimidating” (P12-2). 7 participants simply said that mega-widgets were “too big.”

Games—Fun and games were mentioned in 5 responses with 3 of those responses related to the roller coaster sprayer. The other 2 references to fun and games came up in the context of the car vending machine model selector. In both cases, the participant compared the process to a “game show.”

Accidental Input—Six mega-widget pairings were made because the participant wanted to prevent accidental input. They felt that a larger widget would be more difficult to change accidentally. For example, P3-2 picked the large knob for “Temperature: Dorm” because the finger size knob was “easy to knock around.” P13-2 picked the enormous knob for the dam flow controller because it was a purposeful movement that is “less likely to be an accident.”

DISCUSSION

Interesting Results

A key result seems to be that people imagine “big widgets control big things,” for different interpretations of “big things” as either physically large or conceptually important. This is an application area for further exploration with mega-widgets, perhaps involving studies to attempt to tease out to what extent the size of a control is able to communicate something about the importance or physical size of what it is controlling, and whether this is able to add meaningful context in interaction design.

In our studies, we observed participants often considering precision as a driving factor in using a mega-widget. This may be connected to the idea of importance, possibly indicating

the notion that in some applications, the user would like to get the setting precisely right. Similarly, participants also used the size of mega-widgets to make sure that the widget was not accidentally adjusted through a bump or careless movement. Those who mentioned this, however, tended not to use the “enormous” mega-widgets for these pairings, presumably because beyond some point a larger widget begins to lend itself to being more easily bumped. Further exploration may yield controls which produce a larger range of motion in order to aid in precision while being more ergonomically designed and less prone to accidental input.

Whereas we had largely discounted the idea of physical leverage, some of our participants did not, and for physical or metaphorical reasons still wanted to use mega-widgets to apply leverage. It may be interesting to explore increased resistance or other more pronounced haptic feedback in connection with this notion of leverage.

We were not surprised that fun and playfulness came up in our studies. The value of this characteristic should not be overlooked, because it can be a key enabler of engagement and be very valuable in some settings. A toolkit implementing mega-widgets in an easy-to-use prototyping fashion may prove valuable for educational or similar applications.

One surprising result was that visibility, which was a theme in results from the first study, did not emerge during the second study. It is hard to tell whether this is due to the applications used in the study or some other factor. Because of the increased visibility mega-widgets provide over finger-sized widgets, this is an area worth further consideration.

It is not part of the scope of this work to explore specific hypotheses concerning the construction or efficacy of mega-widgets. However it seems clear from the word embedding-based cluster characterized by the words “mindless, useless, brainless” that some people may respond poorly to mega-

widgets. Future work will need to put a finer point on this reaction, so as to avoid the application of mega-widgets in contexts which might generate negative reactions.

Weaknesses

A weakness of our study approach is our recruitment of participants, which was via convenience sampling on a university campus. Although we did not collect demographic data apart from gender in both studies and college major in the first, it is likely that this led to a fairly homogeneous group of participants. A more diverse group of participants may have led to data which would have contained insights which we were not able to glean from the data we collected. Future efforts at exploring mega-widgets would do well to recruit a broader, more diverse participant set. Different and interesting results may also be gathered from studies involving specific demographics such as designers, children, and educators.

While we did construct a working version of the game Pong which used the enormous knob, we did not include it or other working applications of mega-widgets in our studies. Instead, we asked participants to imagine using mega-widgets in applications. We still felt it important to build working mega-widgets in order to prove the concept and provide a physical experience for participants. A very important next step in future work is to study their use in actual working applications.

We only constructed three types of widgets for each study. While this may have limited the ability of participants in our studies to imagine applications, we felt that a button, slider, and knob were fairly representative of the broader world of physical widgets, and sufficient for exploratory work in this area.

Future Work

We found our use of word embeddings and clustering effective for our purposes. We intended it as an approach which would be fast and avoid researcher bias, and we felt that it accomplished both of these goals as well as producing results which seemed reasonable and accurate. But this does seem to be a new approach, and as such there is need for more exploration and testing.

In future work we would like to address the way in which designers might use these results to elicit specific feelings, which might be useful in specific settings. As with the prior work related to the creation of physical widgets, designers likely need a toolkit that would allow them to experiment at the mega-widget scale for the purpose of designing systems that use the reactions we explored here to achieve their desired ends. Properly executed, a tool kit for mega-widgetscale devices could make the process of designing constructing them much easier.

A barrier to implementing such a toolkit, and to implementing mega-widgets in general, is the heavily manual and labor-intensive process by which objects of this size are crafted. Mega-widgets simply require more work and material than finger-sized widgets. While our decision to modularize mega-widget construction helps, there is much more work that can

be done to enable rapid prototyping and construction of mega-widgets. An obvious avenue to simplifying this process is work in large-scale fabrication, such as breaking larger objects into smaller parts for printing [14, 11] or printing joining members to construct frames [10]. These and similar approaches could greatly simplify mega-widget construction, helping to move research in this area forward more quickly.

An important distinction between our implementation of mega-widgets and “naturally-occurring” large-scale controls is the driving motivation behind their size and shape. Large-scale controls in existing applications take on a size and shape which fits their context, while mega-widgets are scaled-up versions of smaller controls, which creates an entirely new context which is, to this point, largely divorced from usage context. Future work with mega-widgets will need to navigate the balance between making widgets, which are by definition widely applicable in many different contexts, and purpose-built controls whose size, shape, and range of motion more closely fit their usage context.

The large size of mega-widgets also lends itself to exploration of the aesthetic and ergonomic aspects of their construction, which was not a focus of our work thus far. The phenomenon we called out as *Misunderstood Shape Cues* in our first study may in fact point to an opportunity within mega-widgets to explore new shapes and motion profiles in conjunction with larger-sized controls, rather than simply magnifying smaller controls. Such work may also address ergonomics and accessibility, which are both areas for future exploration with mega-widgets.

Also, while we made attempts to provide haptic feedback, this is an area where a great deal of progress could be made. The physical and mechanical properties of the mechanisms, including the haptic feedback they provide, becomes an interesting design and engineering question at larger scales.

The visibility aspect of mega-widgets may also be a fruitful area for further research. Mega-widgets can provide visibility of the actions performed with a control and its present setting, without need for external visualizations such as screens. This may prove to be a useful application in certain situations.

CONCLUSION

We have presented the concept of unusually-sized widgets, which we have termed mega-widgets. Through two iterations of construction and user studies, we have begun to understand user responses to mega-widgets and possible uses for them. Based on responses from user studies, we have identified this as an interesting new avenue for exploration and have helped to set directions for future study. While much work and study remains to be done in this area, we hope that this paper and our work can serve to open the door to inquiry in this area and lay a foundation on which we ourselves and others can build in exploring the world of mega-scale physical interaction.

ACKNOWLEDGEMENTS

This work supported by the National Science Foundation under grant IIS-1406578.

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