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EMERGENCE IN INTERACTIVE ARTISTIC VISUALIZATION

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This research draws on theories of emergence to inform the creation of an artistic and direct visualization. This is an interactive artwork and drawing tool for creative participant experiences. Emergence is characteristically creative and many different models of emergence exist. It is therefore possible to effect creativity through the application of emergence mechanisms from these different disciplines. A review of theories of emergence and examples of visualization in the arts, is provided. An art project led by the author is then discussed in this context. This project, *Iterative Intersections*, is a collaboration with community artists from Cerebral Palsy League. It has resulted in a number of creative outcomes including the interactive art application, *Of me with me*. Analytical discussion of this work shows how its construction draws on aspects of experience design, fractal and emergent theory to effect perceptual emergence and creative experience as well as facilitate self-efficacy.

Keywords: Interaction design; Interactive Art; experience design; creativity; disability; emergence; artistic visualization.

1. Introduction

This paper describes an interactive art system *'Of me with me'* (Seevinck, 2013) for creative participant experiences. This is an artistic visualization that facilitates creative drawing. The design of the system has been informed by a collaborative process of working with community based artists at Cerebral Palsy League and characteristics and theories of emergence. The project and artwork are described and contextualized within emergence and visualization literature. This discussion aims to add to the understanding of artistic visualization and exemplify the potential of emergence for facilitating creative interactions.

This paper draws on a conference presentation at VINCI in 2014 [45]. This paper builds on that work to focus on creativity, both as a characteristic of emergence and in terms of a theory in its own right. This facilitates further analysis of the artwork presented here, leading to an understanding of how it can facilitate 'distributed creativity'. An expanded discussion on visualization is also provided. This reviews Stuart Card's classification to focus on interactive visualization; and reviews of interaction and engagement frameworks from art and experience design researchers are also provided.

The artwork *Of me with me* has since been refined and installed at an art gallery. Additional descriptions as well as documentation of the installation in use are also included. Background to this work is also provided. This includes a discussion of the prototype art system that preceded *Of me with me*, as well as the conceptual drawing efforts with the community artists. These background works combine with the added theoretical discussions to support some insights about the opportunities for facilitating creativity through emergence and across people and artefacts, as well as creating experiences for relating and self-efficacy.

The following section provides a theoretical background and context for the subsequent discussion of the interactive system (section 4). It constitutes a definition and review of some of the core issues in emergence literature, and some summaries of creativity and visualization literature.

2. Emergence

Emergence is a highly debated concept both within, and across, domains. Here it is understood as occurring when a new form or concept appears that was not directly implied by the context from which it arose. This new 'whole' is more than a simple sum or grouping of its parts. For example, in Figure 1 two squares intersect to afford interpretation of a new shape: a triangle. The triangle is the whole that emerges from the interaction between the squares (the parts).

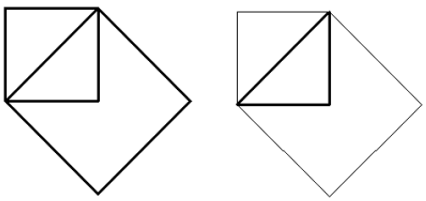

Figure 1 A triangular shape emerges perceptually from the intersection of two squares.

Literature on emergence describes something 'new' as occurring during emergence. For example, as the "*creation of new properties* [23]". Also, "*an emergent form [is one which] displays characteristics not present in its source* [20]". It is heterogeneously new [36] and as described by physicist Crutchfield, this newness occurs when something different to a system's defining (pre-existing) character has occurred. That is, it is 'new' because it is different from what was there before [16]. This new structure is a 'whole', something which is more than a simple sum or grouping of its parts. The notion of the whole draws on the concept of Gestalt theory: "*There are wholes, the behavior of which is not determined by that of their individual elements, but where the part-processes are themselves determined by the intrinsic nature of the whole* [57]". For example, the perception of the whole musical melody and how it is inconceivable from exposure to

separate notes. It is also heterogeneously new and not deducible from those musical notes (von Ehrenfels experiment described in Wertheimer).

2.1. *The observer*

A key differentiator between the various definitions of emergence and a core concern here is the role of an observer. That is, we can look at emergence as being one of two kinds: firstly it might rely on an observer's perception of the emergent structure in order to exist, as is the case with the emergent square shape above. For example, it focuses on their interpretation of a new form or structure. Similarly, the perception of new shapes during design drawing is considered as a process of emergence. This understanding has featured in art, design and Gestalt theory. It draws on perception as a creative process.
Secondly, there are those forms of emergence which are argued in some disciplines, such as physics and biology, as independent of an observer. This 'Physical emergence' includes research contributions from the complex science and physics communities. Physical emergence relates to the occurrence of emergence in the natural, physical world, as well as simulations of this process. The emergence of physical structures in nature includes the ordered formations of interacting individuals or parts; as opposed to groups of them. For example, the typical V-Shape of snow geese flying in formation is an emergent structure or behavior that becomes physically manifest and can be differentiated from a disordered group of birds. The tendency toward self-organization in systems that are not living is also an example of emergence. Processes such as these are also often simulated using algorithms and models that can re-create, at least in part, some of the complex behaviors we see in the natural world. Artificial Life (AL) is one common example, as in the use of cellular automata to describe ant behaviors and Lindenmayer systems to describe organic structures such as trees or the crystalline structure of snowflakes [24, 34, 43, 58]. Within the interactive arts, the system changes and in so doing, presents a new form or structure to the person who interacts with it, for example Rebecca Allen's *Emergence* [3, 4] and *A-Volve* as well as a range of other works by artists Christa Sommerer and Laurent Mignonneau [30, 53].

The role of an observer is crucial to questions about whether or how emergence can be objectively knowable, as well as how it may be inherently subjective. These are important debates and reflect different philosophical understandings of the world – as whether it is objectively knowable and measurable in the first place, whether or not we influence it through our measuring such as by deflecting a particle's direction when we seek to identify its mass; or if we need to anticipate in some sense what a value or signal in a data set *is*, in order to differentiate it from the noise. The resolution of these sorts of concerns is not, however necessary in order to work with emergence. A pragmatic approach can partially reconcile these different epistemologies (e.g. a Positivist stance that assumes the world is knowable; versus a Subjectivism paradigm that believes we cannot separate ourselves from the world we know). This has been previously been done by the author in the context of interactive art [46]. These efforts, partly presented in the taxonomy of emergence described here, can draw on philosophies of emergence from one

domain (e.g. the computational sciences) as a means to identify and render new opportunities for creating and experiencing emergence in the observer, or audience of an interactive artwork. It is this very approach that is presented here with the interactive art system *Of me with me*.

3. Creativity

Emergence is also integrally related to creativity. The relationship is mutually informing and necessary, but not adequate for each. Firstly emergence logically implies creativity when the heterogeneously new whole arises, relatively unpredictably, from the parts. Conversely, creativity necessitates emergence: *"Emergence is fundamental to creative thought in the sense that we find it hard to qualify an idea as creative if it is clearly implied by the preceding conditions* [19]." Creativity researcher Margaret Boden describes the creative idea as *"novel, surprising, and valuable* [6]." She differentiates creativity from emergence through the notion of value in the outcome: something may be emergent but unless it is valued, it is not creative. For interactive works such as *Of me with me* this is a necessary consideration. Here an emergent structure may be created but the value of that structure to the person is a different matter. Boden also differentiates the novelty of the creativity between that which is novel to the person who is being creative or as historically novel [6]. Finally, the quality of surprise is developed to identify three types of creativity. The first is combinatorial creativity where familiar ideas are combined in unfamiliar ways. This requires some expert understanding of the domains being combined. Juxtaposition, analogy and collage in painting are all examples [7]. This is often understood as a mechanism towards innovation. It can also describe the approach of applying theories of emergence from one domain to another, advocated here.

Exploration and transformation are the other two types of creativity. Both relate to one's mental, conceptual space though in different ways. This personal 'thinking style' or 'way of thinking' is made up of a set of principles that define the realm of what is possible within that conceptual space. Navigating this space to identify and make explicit all of its possibilities is exploration; for example identifying the range of possible chess moves or jazz melodies. The exploration of conceptual spaces is analogous to detouring to explore small roads in the countryside. You may come upon a small village and while this is surprising you look back and note it was on the map all along. This is the creative exploration of a conceptual space – the countryside. The countryside itself remains unchanged by your creative activity. "*Exploratory creativity is valuable because it can enable someone to see possibilities they hadn't glimpsed before. They may even start to ask just what limits, and just what potential, this style of thinking has."* This is significant in the context of the art project presented here, since this understanding of more potential can logically contribute to an increased sense of agency, self-esteem and independence. These are valuable design goals when working with a physically disabled community of artists, as the artwork *Of me with me* has been.

Boden's third type of creativity, transformative creativity, can result when the conceptual space is changed or, more specifically, the 'way of thinking' is changed.

Continuing the analogy above, if one were to be able to change it through creative activity, for example reroute the motorway, this would be an instance of transformative creativity. *"A given style of thinking, no less than a road-system, can render certain thoughts impossible – which is to say, unthinkable. The difference … is that thinking-styles can be changed – sometimes, in the twinkling of an eye* [7]." One would think that re-routing the motorway is impossible but it is exactly this type of change that Boden describes as transformative. While that is not a direct design goal here, it will be a matter of the evaluation studies to determine whether or not any transformative creative understandings or behaviours have taken place.

As shown, the understandings of emergence vary across disciplines. Key characteristics of newness, the whole that constitutes parts, relative unpredictability and creativity are, however, common across the domains. Other qualities include the inability to explain it and whether or not the emergent whole has been influenced by feedback from its parts back into the whole. All of these qualities have previously been assimilated to inform a taxonomy of emergence in interactive art [46, 48]. The similarities facilitate an ability to map from emergence theory in one domain (such as the simulation of physical processes) across to effect emergence in another domain (such as design research and the interpretation of new forms). The art system presented here has been designed in this respect, as is discussed in section 5.

4. Towards a deeper understanding of Interactive, Artistic Visualization

Visualization research encompasses data or information visualization through to architectural, scientific, function-based and artistic visualizations. These areas intersect in that all sustain a transformation, or mapping, of information to image. This information can be numeric, geometric or logical data [18] and the resulting visual form is intended to facilitate audience understanding: visualization *"is a process enabling the user to observe, digest and make sense of the information* [41]."

4.1. *Ambiguity and readability*

Information visualization researcher Robert Kosura identifies further criteria for something to qualify as visualization. Of particular relevance here is the need for the visualization image to be actively readable and recognizable as visualization [33]. That is, the image should clearly be visualization and it should provide for unambiguous readings, even if this requires training. Ziemkiewicz and Kosura specifically outline some criteria for readability. These include bijective mapping - the need for a visual element to uniquely and consistently represent a data variable [59]. While the former criteria (mapping information) can be satisfied by artistic visualization, the ability to read and recognize are more of a challenge: art is inherently ambiguous, offering multiple meanings and interpretations to different contexts and audiences. This very nature of art compromises a work's readability. Similarly, works of art may not make the denotive aspect dominant, for example the priority may be an evocative aesthetic that serves to intrigue and engage the audience who could then 'decipher' or 'read' one or multiple

meanings in the work. Kosura proposes a gamut of visualization with pragmatic, clearly readable, recognizable visualization at one end and the sublime or artistic work which is more multifaceted/ plural in its meaning, at the other end as summarized in Figure 2 [33].

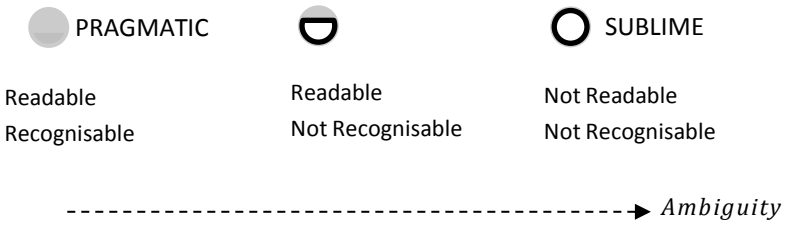

Figure 2 Summary of Kosura et al gamut of visualisations. This can be layered with an understanding of art as inherently open to interpretation or ambiguous.

4.2. *Interactivity in visualization*

Ziemkiewicz and Kosura also differentiate between types of interactivity that a visualization can sustain; arguing a need for 'non-trivial' interaction where the user is meaningfully transforming the data representation. [59] Interactivity in visualization is a significant consideration, described by Stuart Card as *"what makes visualization a new medium, separating it from generations of excellent work on scientific diagrams and data graphics* [13]." Card's earlier framework for understanding visualization emphasises techniques for visualization. It also provides a more detailed consideration of the possibilities for interactivity in this domain. A visual summary of the categories from Card's 2003 work is provided in Figure 3.

Briefly, Card's classification differentiates between information visualizations by looking at the constraints that inform their creation [13]. These include perceptual considerations that inform visual representation as well as data properties. Four categories are proposed. These range across these two dimensions – namely from static visualizations (no. 1 and 2 above) through to interactive visualizations (no. 3 and 4 above), while also differing in terms of the number of data variables or complexity, of the display. The first category of Simple Visual Structures includes representations below or above the perceptual threshold: i.e. direct and easily perceivable with under 4 variables (*Direct Reading*). This subcategory corresponds to the pre-attentive perceptual, visual capability of the human eye [56]; namely that we are able to easily comprehend a limited number of particular kind of visual element. This is typically limited to three. The sorts of visual representations that are visually effective include spatial positioning, length, rotation etc. and have similarly been described within Gestalt theory of perception.

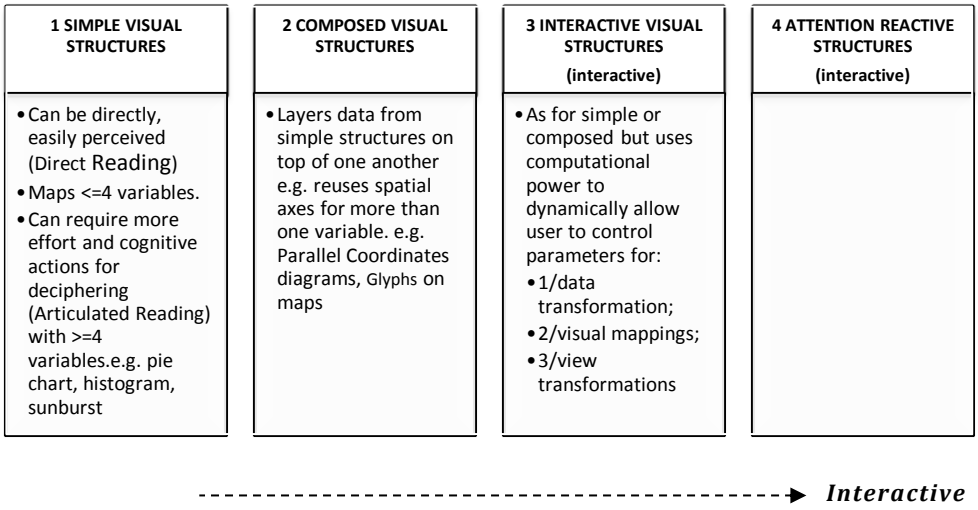

Figure 3 Stuart Card's taxonomy of visualisation techniques is organised in terms of interactivity.

When more than four variables are being communicated in a static display, the level of effort required to make sense of this display tends to go up and the effectiveness of the display reduces. These more complex static displays require multiple cognitive and perceptual actions to read them. Card describes them as *Simple Visual Structures: Articulated Reading Visualizations.*

Indeed Card argues that addressing this difficulty of data density display is a primary design goal when working in this domain. The second category and set of visualization techniques exemplify a typical approach to resolving this issue: where the simple structures are layered or nested to facilitate more efficient comprehension, yet are still static displays, they are *Composed Visual Structures*. Typically here the spatial axes are re-used and Parallel coordinates visualizations are an example of Composed Visual Structures. Glyphs on maps are arguably another example.

The third set of visualization techniques is to use an *Interactive Visual Structure*. Here computational power facilitates user control of data transformation, visual mapping and view transformations of the data. Typical techniques and examples are facilitating dynamic search queries, movable filters (such as the magic lens interaction metaphor), facilitating an overview and detailed view (similar to the lens that provides detailed view as the user interacts across the data display) as well as other techniques for identifying, exploring, manipulating and comparing data variables dynamically. As mentioned, Zienkiewicz and Kusara assert a need for 'non-trivial' interaction. Card's descriptions all facilitate such a change in the mappings or transformations of data to form.

Lastly, Card also goes beyond their description to explicitly articulate the usefulness of a system that 'adapts' to the user. In this *Attention-reactive visualization*, the computer is seen as playing an active role in determining the field of interest: the *"machine is no longer passive, but its mappings from Visual Structure to View are altered by the computer according to its model of the user's degree of interest*". Thus the information that is displayed to a user would depend on their interactive behaviors including their previous navigational path or search history.

Here Card's motivation behind building adaptive systems is to ensure the best use of the system's computational power. Since his paper in 2003, however, we have seen other instances of adaptive interactive visualizations. For example, in the increasingly common use of persuasive advertising [26] one's internet browser history informs a customer profile that drives the nature of advertisements shown to you. This more targeted (yet often unsolicited and arguably invasive) use of adaptive systems is now common practice across internet stores such as Amazon and social media such as Facebook. This sometimes unpleasant example is just one aspect of a larger picture: engagement. It is worth noting the potential of an adaptive system to engage the system user in a broader context, without seeking to persuade them. As is discussed in section five on engagement, adaptive systems have also been identified within the interactive arts, further indicating the potential of looking across domains for new approaches, opportunities and solutions. As also becomes evident there, Card's differentiation between static and interactive forms is also mirrored in some understandings of the digital arts.

4.3. *Direct Visualization*

Information visualization is characteristically reductive. That is, when data is transformed and mapped to geometric primitives, there is a loss of information, context and a change of meaning. In 2010 Lev Manovich identified a counter trend in artistic visualization, one which he describes as 'direct visualization' or 'visualization without reduction'. Here the data is itself directly present in the final visualization outcome: it is *"reorganized into a new visual representation that preserves its original form."* The data may be sampled to reduce the size, but it is not translated or qualitatively changed into another form. In this sense it is not subject to 'qualitative reduction' and the result is the *"preservation of a much richer set of properties of data objects* [37]." Examples include *Cinema Redux* by Brendan Dawes (2004). Here film stills, sampled from a movie at one frame per second, are presented as a grid layout with frames adjacent to one another on a static, wall size installation. Similarly, in *The Art of Reproduction* by Viega and Wattenberg, the many different reproductions of a Vermeer painting are sampled across the internet and compiled into a single mosaic visualization "*we've taken fragments from different reproductions found on the web, and (with a nod to David Hockney) assembled them back into whole*s." Importantly for Manovich, the original data source images are retained in the final composition and the diverse range of their inaccuracies in reproducing the original Vermeer painting is immediately evident, given the mosaic incorporates pieces

of them to show that diversity of color and texture. Viega and Wattenberg describe the result as a "*tapestry of beautiful half-truths* [55]."

Another interactive artistic visualization by Viega and Wattenberg is *Fleshmap Touch*. In this exploration of sensuality, data for erogenous zones is visualized in a way that is similar to a tag cloud, but in the form of a web-based interactive. Specifically, the visualization uses photographs of different areas of the human body. These are sized according to their significance. One can also navigate and explore the dataset using those same photos [54].

Like the two previous examples the data presented in *Touch looks like* the data that was collected. However, unlike the above examples, these are not the actual data that was collected – in fact the data collection in this project did not involve photographs at all. However, it does retain some similarity to direct visualization because there is a visual likeness to the data source that is communicated and, in this sense it is in keeping with the non-reductive philosophy behind direct visualization – that the quality or context of the data be retained.

The use of direct visualization is not, however without its drawbacks. That is, the increased specificity can also inhibit the ability to generalize to other contexts. For example by focusing observer attention on data there is a danger of detracting from their ability to generalize or interpret higher order patterns. Furthermore, reductive approaches to visualization utilize exactly this focusing and abstraction in order to highlight any new trends, even though these may be restricted to that abstract domain.

Finally, where appropriate, visualizations that are either direct visualizations such as *The Art of Reproduction*, or that pragmatically extend its philosophy such as *Fleshmap Touch* will tend to communicate meaning more richly and beyond the data sample itself. As such, they demonstrate the potential for information visualization designers to attract and engage the visualization audience. Audience attraction and engagement are now discussed.

5. Engagement and Visualization

While the effectiveness of visualization remains critical, it has also been argued that designs need to engage users: attracting and satisfying them on another level. As psychologist and well-known champion of emotional design Don Norman asserts "*Attractive things work better* [39]". User experience designers in the field concur: "*We can't just make designs easier to use anymore. We have to make things people will want to use. When designs are fun to use, people will want to use them. So we have to make things that are fun to use* [44] ."

Norman identifies the audience processing of input in terms of three levels: *Visceral, Behavioral and Reflective* [39]. The first and least sophisticated of these layers of sensory input processing in the brain is the *visceral* processing layer. This '*automatic, prewired layer*" can be simply understood as similar those cognition abilities we are born with, or the basic brain functions that dictate the body's 'fight or flight' responses. As the layer closest to sensory input and furthest from higher brain functions of analysis, it is the

processing that responds to the sensual aspects of a design such as color, texture, comfort, hot, cold etc. The second layer of processing is *behavioral*, so named as it controls all the brains day to day behaviors. Finally the *reflective* level is the contemplative level. It relates to how we might reflect on our behaviors and includes things such as how we perceive of ourselves – aspects of pride, sense of achievement, vanity all come into play here. In his text on Emotional Design Norman describes how these different levels work together to inform a person's perception and experience of something and how different people will tend to priorities different aspects. This is significant in terms of interaction design because, as Norman points out, where something is attractive but there may be some elements that are not as robust as they could be, the attraction appealing to our visceral level of processing can mitigate the fault's impact on our more analytical, behavioral processing. Furthermore, he cites studies where something which is attractive AND effective is actually understood as more effective than another, functionally identical system [39].

Other interaction design considerations can also be useful for considering information visualizations. The following section reviews two additional frameworks. At the end of section 5 these frameworks are briefly reviewed as they apply to two other examples of interactive visualizations.

5.1.1. *Interaction and engagement*

The two frameworks of visualization above have each revealed key areas for Interactive, Artistic Visualization: ambiguity in the first and interactivity in the second. In this section Card's view of interaction is unpacked further and compared with an aesthetic understanding.

As outlined above, Stuart Card describes visualizations as ranging from not interactive at all through to something which is interactive, through to that which also adapts to the user. Edmonds has similarly differentiated between different kinds of visual art. This is particularly useful when discussing interactive art because this rather new area entails audience response. In this sense it is quite distinct from the more traditional arts. The classification of art put forward by Edmonds and his colleagues has evolved over the last 30 years [15, 18, 21] and is pictured in Figure 4. The primary differentiator is whether or not an artwork is passive or interactive. A secondary consideration is then applied: that of change, namely whether it is static, dynamic, or varying. Four classes were proposed in 2004 [22]. These are (1) the 'static passive' or 'look don't touch' category, including traditional visual art such as painting. The second class (2) is the 'dynamic passive' category. This is dynamic artwork where the observer is still passive as in the first category. An example of this is video art. The remaining classes are both forms of interactive art, that is, they fall within the 'dynamic interactive' category. This is where an art work changes with the peoples input, or participation; and the viewer can change the performance of the work. The change may be a simple navigation or branching structure of options, or it could be include generative modeling techniques as in the work presented here.

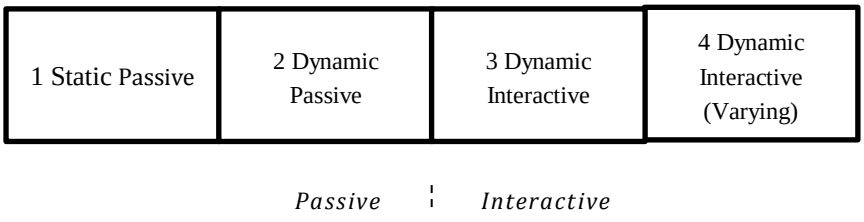

Figure 4 Edmonds et al's classification of art differentiates between passive and interactive forms.

Edmonds and his colleagues also differentiate a specific subcategory within the dynamic interactive class. This is the Dynamic Interactive (Varying). This describes work that is unpredictable due to a modifying agent that changes the specifications of the system. For example, he describes his 'learning interactive video constructs' where the participant interaction is interpreted by the systems agent to shape it over time. Here an agent has been added in to the system and this software changes the rules being used by the system, operating at a meta level. For example, it assesses the viewer data (by parsing a recorded history of interactions and analysis) to determine certain conditions. "...*As it learns, it changes the way that it develops rather than simply changing the stimulus-response rules that govern its behavior"*. This agent software is a generative system. For example, in Edmonds' 2004 interactive artwork *Heron*, vertical line imagery displayed on a screen becomes thinner as more movement is detected by the sensors. In this sense the work is operating as an interactive dynamic work. However there is also a meta-rule. This keeps count of the duration within the preceding 24 hours that a person has stood still in front of the work. The satisfaction of this meta-level condition alters the immediate performance of the system; for example it may or may not be colourful in the graphic visuals displayed. This is an example of where the rules for system behavior are themselves changing; i.e. of a Dynamic Interactive (Varying) work.

Adapting the response or rendering field of an interactive visualization was also suggested by Stuart Card, as reviewed above. This is with the aim of increasing the efficacy e.g. conserving computational power of the work. In *Heron*, a similar approach is used to monitor the audience at a meta level, but for the purpose of engaging that audience. Here the adaptive or varying nature of the interaction affords a system that is anthropomorphized: it appears to be *shy*. It is hoped that this example and the comparison of views of interaction starts to reveal how interaction is understood, and what its potentials are, for and across disciplines.

5.1.2. *Why does experience matter?*

Things don't just exist in the world, they are experienced. Along with the input we receive from our senses are all the other aspects of perception, memory as well as our humanity. These all arguably contribute to our understanding and experience of the

world. Given that interactive systems - visualizations or artworks or both – are experienced, it is logical that the people who build these systems consider the factors that inform experience.

For experience designer Nathan Shedroff, an experienced event begins with *attraction* [52]. This is what has initiated the event. It may consist of cognitive, visual, auditory or some other signal to any of our senses. It may be intentional and based on our need or it may contextual, incidental or on an interface. In another context, advertising exemplifies this by seeking to attract our eye or get our attention through bright colors, lights or sounds.

Following this initial attraction is *engagement* – the experience itself. In order for this to be successful, it must be sufficiently different to the surrounding environment, as well as important enough, to sustain a person's interest. Third is a *conclusion* or resolution of a kind. This should provide meaningful closure to the experience. Finally, it is also possible for an experience to have an *extension*. It may be prolonged, bridged to another experience, revived etc.

A similar framework for experience has been articulated by Edmonds, Muller and a Sydney Powerhouse Museum curator, Matthew Connell [21]. They reflected upon the installation of artworks at that museum to identify some successful characteristics of experience. These are threefold: *attract*, *sustain* and *relate*. That is, a system needs to *attract* an audience in the first place, similar to Shedroff's description of attraction above. Second, the factor that determines whether the audience moves on, or remains, is its ability to *sustain* audience interest. This is also similar to Shedroff's notion of engagement reviewed above. Finally, *relating* refers whether an audience member feels an affinity with the work; whether they are able to relate to it or not. Examples of relating to a system include telling others about your experience or coming back to interact with it again.

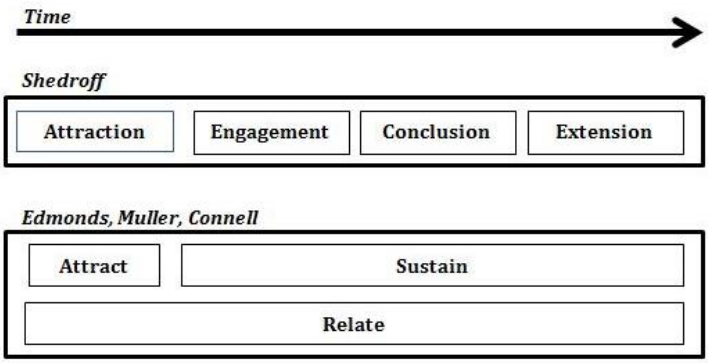

Figure 5 Shedroff (top row) and Edmonds et.al. (below) describe experiences with similar qualities.

Shedroff and Edmonds et al. both identify the initial attraction that the audience may feel towards a work as integral to their subsequent sustained engagement with that work

Of course one is able to relate to an artwork during interaction and not only afterwards. Thus while Shedroff's description of experience is chronological, Edmonds et al are more focused on some of its qualities.

In certain situations the approach of direct visualization described above may serve to increase audience engagement with visualization. For example, it may be that the characteristic richness of the data representation in a direct visualization can strengthen the sensory attraction and corresponding *visceral* processing of that information input. From the perspective of both Shedroff and Edmonds et al., if the data in a direct visualization has some sense of familiarity to the audience it may also extend the design to them personally, or, put another way, increase their ability to *relate* to it.

5.1.3. *Experience critique of interactive visualizations*

Further exploration of the Norman, Shedroff and Edmonds et al. frameworks of experience is possible by reviewing other works. This section critiques two recent interactive visualizations targeted at the general public.

The first example is *Spotlight*, a 'do-it-yourself' infographic based on Census data. Hosted by government agency the Australian Bureau of Statistics (ABS), this website aims to increase the relevance and significance of the national census to the Australian public: *"Shine some light, and see what kind of a story Census data can tell you about you* [1]." While interacting with the Flash interactive the user selects responses to questions that correspond to that in the Census such as gender, age bracket, location etc. These answers are contrasted with the actual data for corresponding regions and demographics from the 2011 Census. This maps the representation of the user against the larger Census dataset, contextualizing them. This arguably also results in facilitating affinity and, in Edmonds terms, *relation* with the work. A personal infographic image is created at the end of the interactive experience that can be downloaded and saved. This concludes the engagement as well as giving the user something that they can keep and share. This may result in further *relating* and *extending* behaviors such as sharing on social media or telling others about it.

This example can also be critiqued in terms of Don Norman's three levels of information processing. It can be argued that the interactive app's audio narration and dynamic, fluid graphics work on a *visceral* level, stimulating our auditory and visual senses. On the other hand, choosing the appropriate response to sensory input is an everyday *behavioral* activity. Finally, the insight that one gains from seeing oneself compared to others can afford critical reflection on oneself, for example pride or dissatisfaction. This latter aspect is working on the *reflective* processing level. It is also quite unique, revealing perhaps the most significant characteristic of this particular interactive visualization.

The second example of engagement with interactive visualization is *Play to cure: Genes in Space* [40]. As the name suggests, this is a game. Specifically, it is a gamification of crowdsourced data analysis. Sponsored by the UK Cancer Council, this is an effort to engage the online public in the visual data analysis needed to process the

large amount of medical data. The aim of the project is to find a cure for cancer. Player interaction is twofold. In the first instance, the player is presented with a dashboard and the task of plotting a line through the densest section of a noisy line graph display. In the second part of the game, this line is a route through an asteroid that the player, as a spacecraft pilot, must navigate. Now the player is presented with a spacecraft cockpit and heads-up display, while their previously selected plot points are rendered as hoops to navigate through and they also have the ability to fire at oncoming asteroids. While the first part of the interaction has some clear resemblance to analyzing data (the line graph looks like a data sample), this is less obvious in the second part. It may be that only first part engages the user in analyzing data; or it may be that the second is also doing it but less obviously so. Indeed the second, more immersive and playful aspect does not appear to present new data for interpreting but could be a mechanism for checking the player/analyst's accuracy or consistency of engagement. From a visualization design perspective both approaches have merit.

While the means of data analysis employed in *Play to cure: Genes in Space* may not be entirely clear, the mechanisms for engagement can be more easily identified. Perhaps most obvious is the playful framing of data analysis in terms of a flight simulator or arcade game. This rendering of the second interaction task is intended to attract the 'gamer-analyst'. Basic, *visceral* level information processing is used in the second, flight simulator experience. That is, it relies on reflexes to navigate obstacles and goals. This is also consistent with the attraction of the arcade game genre– the high arousal and adrenaline rush that accompanies these activities. On the other hand, *behavioral* level processing is most prevalent in the first part of the gameplay where the gamer is completing a complex task to plot their route. Finally, the ability to learn from the gameplay and analysis, as well as synthesize the understanding of each part of the interaction experience (or each part of the mission) is something that requires a higher level processing again – the *reflective* level of processing. This facilitates reflecting and refining one's behaviors for the next game, getting better at the gameplay (and, by extension, at data analysis).

Play to cure can also be critiqued in terms of Shedroff and Edmonds' frameworks of interactive experience. For instance, the high state of physical arousal created during the second flying part of interaction arguably *sustains* a corresponding high degree of participant focus on the game, something which may also contribute to player engagement. Furthermore, each game play is a mission whereby one must process an asteroid belt – or, in this case, dataset. This mission follows a narrative structure: starting with the establishing of the story context through mapping the mission route, through to the subsequent action of flying the craft and dodging or blasting asteroids, through to the completion of the mission and final revelation of one's score. Broadly speaking, this follows a *dramatic arc*. Such a narrative structure arguably helps also to *sustain* player interest and engagement in the analysis of the given dataset from start to end: we want to know how we scored! Finally, the ability to see one's score and share these outcomes

with others through social media has the ability to *extend* the interaction experience for the player, while also facilitating *relating* behaviors.

Understanding the design of information visualization in terms of these frameworks may help to increase audience engagement and the success of works, particularly for lay audiences and in crowdsourcing web or museum contexts.

Interestingly, in plotting the flight route in *Play to Cure: Genes in Space* one must identify visually salient properties to find 'the signal in the noise'. Put another way, the game player must look for and interpret specific visual features and in this sense this example can also be understood as an instance of perceptually emergent visualization. The following example of interactive artistic visualization *Of me with me* also utilizes perceptual emergence, but as shown this is in a more comprehensive way that explores the inherent creativity of emergence as core to the experience.

6. Of me with me (2014)

Of me, with me (2014) is an interactive art system and creative drawing tool created by the author. The installed artwork consists of a drawing tablet and stylus, with a monitor, personal computer, internet connection and weblog for publishing (see Figure 6, 8 [38]). Participants make marks with the stylus and a black line is rendered in real time on the

Figure 6 Installation of the art system *Of me with me'* (Seevinck 2014) at the Redcliffe City Gallery. Collaborating community artist (top left) and gallery visitor bottom right. Images created can with the stylus on the tablet can be seen on the monitor and saved for automatic publishing to a blog. Photography courtesy A Hearsey 2014.

monitor. As the participant draws, grey lines are also rendered in real time, 'echoing' or

'shadowing' their gesture. These echoing lines are scaled, rotated copies of the original incoming line, placed along regular intervals of the incoming curve.

This work can be considered an artistic visualization that facilitates creative experiences by employing a complex model for emergent structures. It is ambiguous in meaning, providing opportunities for different interpretations by different people. It is also an example of a dynamic interactive system. Other aspects of this artistic visualization are discussed later. First, the work and its origins are described.

6.1. *Artwork concept and history*

The work comes out of collaboration by author and artist Jen Seevinck with community artists at the ArTel Cerebral Palsy League facility. ArTel is a fully functional print and visual arts studio for local artists with Cerebral Palsy, the neurological disorder that affects physical abilities. ArTel is also a part of the large non-profit organization Cerebral Palsy League [14]. The artists here vary in physical dexterity and mobility. They have significant potential support from the staff. This can be by loading paint on brushes, by attaching brushes to a stylus, or simply help setting up and cleaning up. For some, the support is necessarily also more extensive, for example a carer may provide steadying hands to help the artist hold the brush while they are painting. Overall the intention is to support the artists and facilitate free artistic expression as much as possible; something which is not insignificant in its value, given the extent to which they must depend on others in most situations.

Elizabeth Saunders and Robert Oakman are key print artists in the ArTel community, with regular exhibitions locally. We collaborated over a year and half timeframe to exchange ideas and concepts. These have informed a project and overall body of work, *Iterative Intersections* [47]. This body of artwork includes digital and paper-based sketches, the interactive art system and visualization *Of me with me*, Seevinck (2014) as well as a prototype system *Iterative Intersectioning (2013)*. The project has been documented on a blog since inception in 2012 [38] and is demonstrated in a brief video online [32].

A core theme in the body of work is the creative process of collaboration, specifically as this informs visual forms. This theme developed as we worked together ourselves. More specifically, it is by working together to make art objects that a 'conversational' exchange took place between us as artists. The nature of this process has gone on to inform our mutual understandings as well as evolve our works. Two early stages in this process, and these creative conversations, are described next.

6.2. *Iterative Intersectioning interactive art system (2013)*

The final artwork *Of me with me* is built in the open source processing environment Processing [27]. A prior, prototyping version created in the Derivative Touch Designer software environment [31] was demonstrated at the Creativity and Cognition conference in 2013[47]. While this earlier version also scaled, rotated and translated the incoming curve, the interaction with that visualization was different. In this earlier application

Iterative Intersectioning, the user would draw a curve then move a selection area onto the curve to specify the segment for generating the echoing patterns. Unlike *Of me with me*, where the whole of the participant's curve is copied, translated and rotated onto itself; in *Iterative Intersectioning* the participant has a two-fold interaction. First they draw the curve and then, secondly, they must select the zone for interacting with this curve. The selection is done by moving a square selection zone around the screen, with a mouse/stylus and keyboard key combination. Copies of whatever line segments fall inside this zone are rendered on screen, in real-time and the feedback is also immediate. However, there is an added step of moving the selection volume. This can be understood as facilitating both 'explorations' of one's own curves that you have made and as 'curating' or editing that curve. This aspect of the work can be understood as operating on the highest, *reflective* level, when reviewed in terms of Don Norman's levels of information processing.

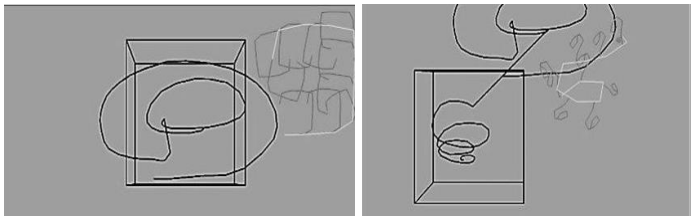

Figure 7 In the *Iterative Intersectioning* interactive art prototype a cube volume selects the part of the curve which is rendered back, in response to the participant - here depicted in light grey and white.

The *Iterative Intersectioning* interactive artwork, while promising technically, was redesigned for a number of reasons. Firstly, it was constructed in a proprietary environment (*Derivative Touch Designer*). This necessarily implied a high cost for the project collaborators, the artists at ArTel. Secondly, the necessity to facilitate two mode interaction (a different mode is used to select than to draw) was decided to be too cumbersome for the target demographic; some of whom are ArTel artists with difficulty maintaining multiple or extensive gestures.

In contrast, the final *Of me with me* iteration has a free executable file and relatively low demand for computer rendering power. This makes it much more suitable for the community arts and disability sectors, who typically have limited financial resources. The interaction is also 'flatter', with only a single mode of interaction. That is, all aspects of the drawing are visualized immediately and there is no selection or curation involved. This facilitates simpler use, but it is also a meaningful difference as this new system affords an uninterrupted 'flow' of experience. That is, while in the earlier version of the work it was necessary to select/curate a piece of a curve you have already drawn, in order to see its 'echoes', in the new work these echoes are rendered instantaneously, as soon as stylus pen touches the surface. The immediacy of this feedback is intended to promote an uninterrupted and, in terms of the Edmonds et al. framework, *sustained* participant

experience. While the cost of this is the loss of 'curating' or 'exploring' one's past gestures and curves, the benefit is immediate play with your line and an intricate, patterned, mirror of your gestures.

6.3. *Iterative Intersectioning: co-drawing*

As explained, the creative collaborative process between Seevinck and the community artists at ArTel are a key aspect to the project. It is also, however, one which has informed the software development of both interactive art systems (*Of me with me* and the prototype *Iterative Intersectioning*). This discussion describes our creative and collaborative drawing process that informed the concept behind software development. It also contextualizes this within artistic and playful interactions.

Firstly, our process of creative and collaborative drawing involved the exchange and alteration of drawings by each artist. It is a process that is analogous to a dialogue or conversation. This was between Seevinck and Saunders or between Seevinck and Oakman. It consisted of passing work between parties, interpreting it and drawing or working back into it, before passing it back; in a process of taking turns.

Secondly, our process can also be contextualized within artistic practice and play. The Surrealist art movement provides an immediate reference. In Surrealist Andre Breton's game of the *Exquisite Corpse* [10] the first player (artist) will draw a creature's head and the beginning lines of a neck at the top of a page. This is then folded over so that other players will not see their image. The paper is subsequently passed to the next player, who has only the neck lines to go by to guide their subsequent drawing addition. This player adds a torso and lines for hips before similarly folding the page over to hide their contribution. The paper is passed along again to another player who also adds something to the figure. Once again this is without knowledge of the drawings that preceded their efforts. The process continues with feet (or tentacles!) until the image is deemed complete by a player. The resulting composite is typically a surprise to the players, a Gestalt made up of their individual creative contributions.

Another interaction which has also informed this co-drawing effort and the interactive artworks is the children's game of *Telegraph.* Here the first child whispers a message in a second child's ear, who then repeats what they heard (or think they heard) quietly so the others cannot hear, in the ear of a third. The process repeats along a line of children, analogous to a Telegraph line. The premise is that the message mutates or changes in some way, as the transfer of whisper to ear is not without error. The last child to hear the message, i.e. the last child in the line, will then speak the message they received aloud for all to hear. Similarly the child who started the process will speak their message aloud. The final message and changes between the two are typically a surprise, and a mutation of the original phrase. The game is interesting in terms of how an original statement can be perceived and interpreted differently as it passes between people.

The exchange of these creative drawings operates in a similar way.

While this process allowed for the creative exchange between artists as well as the creation of these 'co-drawings', the logistics of the effort meant there was a, sometimes

significant delay between exchanges. For example, the new media artist would wait for the community artists to complete working on their drawing or painting (10+ minutes, not including any drying time); while the digital processing of this image would take one or two hours but the subsequent opportunity for meeting might be a week later. These interruptions to the creative conversation between the artists meant that it was difficult to *sustain* interest in the shared experience. The final interactive artwork, does however address this.

Importantly, the concept of creative exchange became embedded in these paper-based drawings. At the same time the process was also supported by these same artefacts. Example drawings produced from this process are shown in Figure 8 [47].

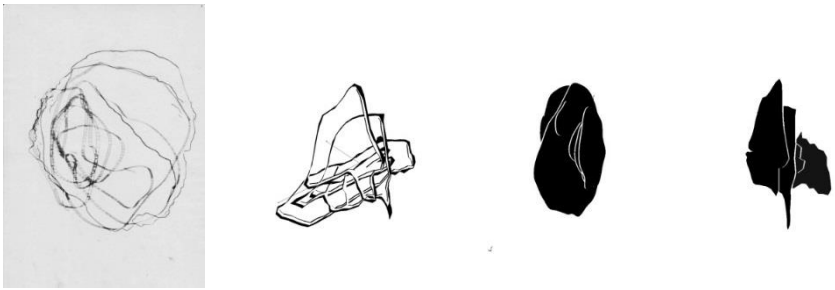

Figure 8 Left to right: Iterative intersectioning 2, Saunders and Seevinck [61]. Print 32x24cm. Iterative intersectioning 1.2, Seevinck and Oakman, [62]. Print 28x24cm. Iterative intersectioning 1, Seevinck and Saunders, [63] Print 28x24cm. Iterative intersectioning 1.1. Seevinck and Oakman [64] Print 28 x 24cm.

7. Software informed by the conceptual structure

As described above and exemplified by the creative co-drawings of Figure 8, the concept behind the interactive artworks is one of *creative collaborative exchange*. It is analogous to a *conversation* between people. These ideas have been of primary importance to the design of all aspects of the project.

Within the interactive art systems it has been implemented through visual 'echoes' where participant gestures are mimicked back to them. As with the creative paper drawing exchange, the participant then assimilates this new input and their understanding changes. The feedback from the system changes them and their subsequent gesture in working with the art system.

This feedback loop and concept of exchange is also evident in the software implementation of the interactive art systems: a participant's drawing gesture is sampled as a curve and stored as a series of points in Cartesian space. The subsequent feedback to the participant is a type of 'drawing into' their drawing: firstly the original curve is divided into segments and secondly, each segment is replaced with a scaled version of the input, original curve. This creation of the system response is visually described and illustrated in Figure 9.

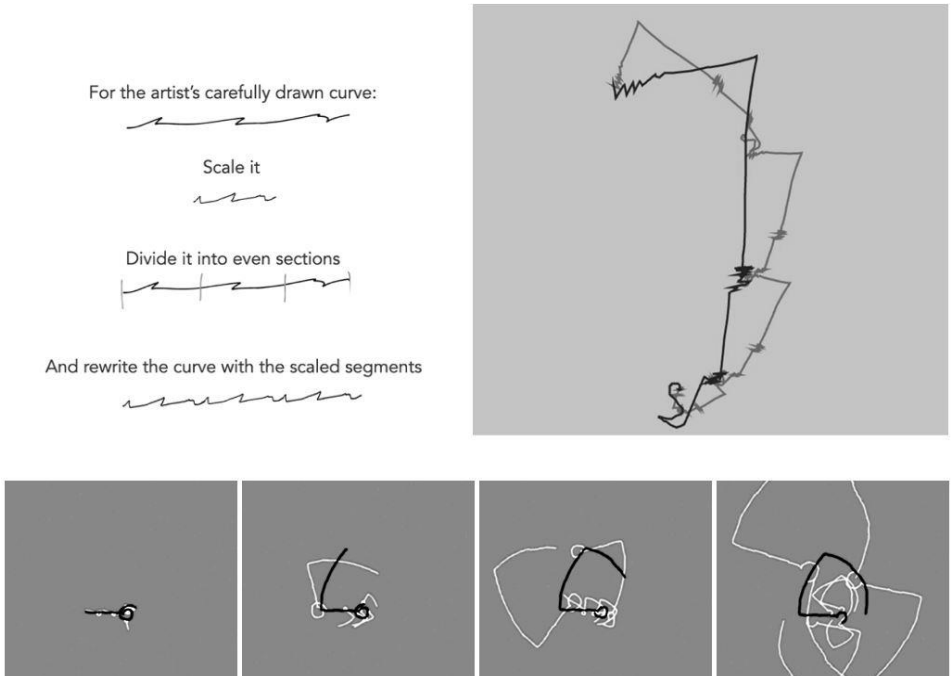

Figure 9 *Of me with me* (Seevinck, 2014). The self-replicating quality of the Koch fractal informed the visualization process. (Clockwise from top) A visual explanation of the software, a single still image created by a participant interaction and a series of four chronological images of participant interaction with the work. The darker lines are the participants direct action.

7.1. *Fractals and emergence in Of me with me.*

Another aspect to the structure of this program is its fractal nature. A fractal is a geometric shape whose part curves are identical (statistically or exactly) to the whole. Fractal shapes have three characteristics: they are (1) self-similar and (2) formed iteratively. Self-similarity is when the parts are similar to the whole. In nature, fractals will exhibit statistical self-similarity; approximating the representation of the whole. The part curve in simulated computer based fractals is typically exactly identical to the whole curve, unless some randomness has been included in the calculations. The third characteristic (3) is their non-integer, or 'fractal' dimension. For example a fractal in space can occupy more than a line (2D) and less than a plane (3D) [25]. This is because as we try to define these objects in Euclidean space, we find that the iterative structure means that its size is continually increasing: as we look at it more and more closely we can see more and more detail i.e. the self-similar structure reveals itself at subsequent levels of magnification. (Determining the length of fractal curve is dependent on the unit of measure; as this unit decreases in size the length of the curve increases.) A flat piece of paper clearly occupies a plane, but if it were crumpled into a ball would it then be

considered three dimensional or is it still two dimensional, or is it somewhere in between?

There are a number of ways to create fractals. Popular mechanisms for generating fractals this include the string replacement modelling from Lindenmayer, or L-Systems and Iterated Function System (IFS). One simple method relies on a starting shape, the initiator and a generator, or collection of copies of the initiator shape, and a rule for combining these. For instance, within the generator all copies of the initiator are to be replaced with a scaled down version of the generator. The Koch curve can demonstrate this. It is one of the first descriptions of a fractal and is named after Swedish mathematician Niels Fabian Helge von Koch. This is also the method that informed the software implementation behind the interactive artworks presented here, as illustrated in Figure 9.

7.2. *Software design*

In *Of me with me*, the drawing stylus is tracked over time and across the screen so that the X and Y coordinates for its position are stored in a two dimensional array. As the participant drags the stylus across the surface, subsequent positions are sampled and added on to the array, to a maximum set length. One aspect of this design is the implicit rendering of gestural speed. Furthermore, because the subsequent positions of a tracked stylus input are being stored the participant's movement angles can also be calculated. The positions (vertices) are connected as lines, using the Processing shape class but without filling it. The array itself is also copied for translating and scaling and rotating. The transformations occur in object space before the copies (grey) are returned to world space and rendered back alongside the original mark (black). Translation destinations are calculated by sampling from the source curve (breaking it into a predetermined set of span lengths). The system runs in real-time so that the iterating curves, including their position, size and rotational values are continually changing. In this way the participant's drawing movements occur simultaneously with the 'echoing', fractal imagery of system response. The software environment used is open source Processing software [27]. A series of screen captures from interaction over time is pictured in Figure 10 along with a still image from participant interaction with the work (top right). Push buttons for saving images and clearing the screen are also implemented in the work. These facilitate clearing the screen as well as saving images out. Saved images are automatically published to the project weblog [38] pictured in Figure 10.

8. Discussion

The body of artwork and, specifically, the interactive artistic visualization *Of me with me* are now discussed in terms of the theoretical frameworks provided. Firstly, the interactive system is framed in the theory of emergence. Next, the quality of experience that the design of *Of me with me* affords is analyzed. This discussion reviews experience in terms of both independence and self-efficacy to meet co-artist needs and in terms of theories of experience design reviewed above. The body of work is then critiqued in terms of

creativity theory. The section concludes with a discussion of the future work, namely evaluation of people's experience of the system.

8.1. *Emergence for Creative Perception*

As discussed earlier, physical processes such as snowflake crystals or birds flocking can be simulated using computational systems. While such systems are instances of physical emergence, they also often hold a meaning for an observer. For example, the perception of the 'V' shape of a flock of snow geese can be classed as an instance of perceived or perceptual emergence, similar to the emergent square example in Figure 1 and consistent with the understanding of emergence in the design research domain. This is in addition to the fact that the system is also an instance of flocking behavior, benefitting each individual bird through reduced wind resistance. The ability to draw on mechanisms for modeling emergence in one domain, such as complexity theory, in order to effect emergence in another domain is an underlying design approach in *Of me with me*. Specifically, in this creative work the participant gestural data (point positions etc.) function as a mathematical set for a fractal simulation. This fractal simulation affords recurrence as well as patterning to support creative behaviors. It is analogous to the Koch curve fractal model for snowflakes. In the software for *Of me with me*, an artists' initial gesture is recorded as a series of points in space. This mark is then scaled and iteratively copied onto that original curve, as shown in Figure 10 and described in section 7 above.

The main, top right image in Figure 10 above can be interpreted as an emergent composition: an unanticipated new form that has appeared from the initial mark made by the artist, but which was not directly implied or predictable from that first mark. It has visual structure, a sense of being a 'whole' that is more than a simple sum or grouping of the different parts that make it up. For example, each copy of the original artist's mark is rotated according to the original mark, but also in a way that relates to all the other marks. Similarly the scaling and transforming of all these copied marks is neither meaningless nor independent of one-another; rather there is a sense of a 'definite structure' or organization, a Gestalt, as it is defined in the Oxford Dictionary: *"...an organized whole that is perceived as more than the sum of its parts*" [60].

The theoretical understandings of emergence and how it is inherently creative, as well as the images that can be created with this system, indicate a strong potential for this work to effect emergence and creativity.

8.2. *Experience design in Of me with me*

A significant point here is that the images that are rendered back to the participant are all of their own making: these are their own marks. In this sense the work facilitates drawing *with* oneself, by interacting with elements *of* oneself. This is particularly valuable as it can afford a sense of ownership of the mark.

Also, the fact that audience gestures are rendered back to the audience as part of the final drawing output, means that work can be described as an instance of *direct visualization*.

The recognizability and immediacy of the systems' response to user gesture are anticipated to increase usability, user confidence and sense of self-efficacy.

Design for self-efficacy has also been addressed by maximizing the accessibility of the work. In the first instance, there has been an effort to address the cost of the system by redeveloping for a free and open source software environment. Secondly, the design of the interfacing modality has been informed by what is currently in use by the ArTel artists i.e. paintbrushes and pencils. The choice of a tablet with stylus is intended to support the same grasping by hand or taping to a head pointer or elbow scaffold as a pencil would, and in this way facilitate similar movements for creative activity. Thirdly, the application also facilitates immediate publishing of images online. While this facilitates quick and easy access to those images for further work or sharing them with peers, friends and family, it is also a form of exhibiting. It is anticipated that this is empowering as it facilitates a wider reach for these artists and access to the wider internet community to show their work in public as well as an ability to work with digital online technologies. Similarly, since the system is capable of publishing saved images to the internet automatically, there is the added ability to find one's images online and download or share these using social media. This therefore has the potential to *extend* the experience and facilitate *relating experiences beyond the interaction*.

The work also facilitates *Relating* experiences in another way, through the immediate understanding and feedback that the lines drawn are the participant's own. In experience design, where a participant sees an element of themselves they are more likely to relate this to themselves. In terms of the community context within which this project has been pursued, this aspect can support increased self-efficacy and esteem.

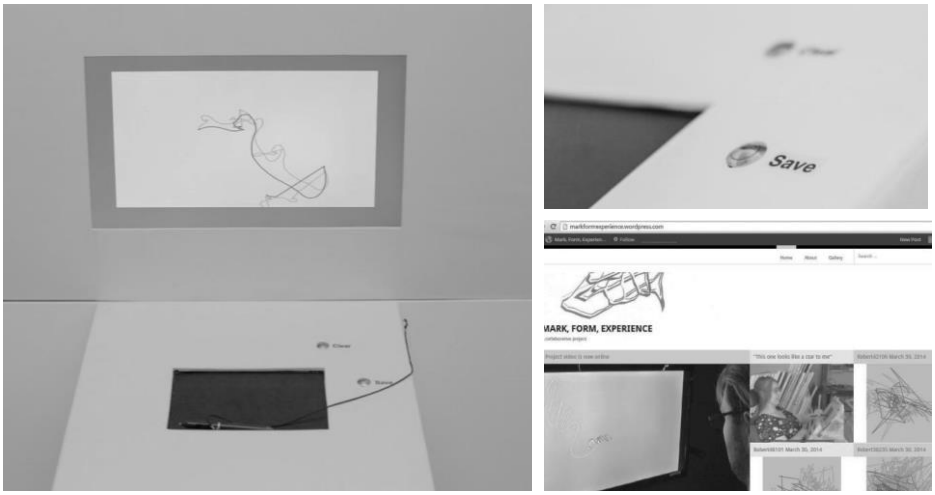

Figure 9 Installed artwork *Of me with me* (Seevinck 2014) features a stylus and trackpac along with save and clear buttons for interface. Images saved by the audience are posted online to the blog (right).

The direct presence of the original data may also increase the *attraction* of the work more so than if the audience-artists' original mark and identity not been as clearly evident to him or herself.

Finally, as mentioned above, this system differs from the prior system *Iterative Intersectioning* through immediacy of feedback. This is intended to promote an uninterrupted and, in terms of the Edmonds et al. framework, *sustained* participant experience. While the cost of this is the loss of 'curating' or 'exploring' one's past gestures and curves as in the previous work, the intention is that this better facilitates an engaged, sustained experience.

8.3. *Distributed and other types of creativity in the artistic visualization*

The previously described iterative exchange of drawings employs some of the same mechanisms for creative expression currently used (and supported by carers where necessary) at ArTel; namely the use of pen, pencil or brush on paper. As mentioned and described previously, this creative collaboration revolved around 'taking turns' to make drawings together [47]. These drawings became the memory of the drawing activity. They are key elements of the creative cognition process of drawing. They were handed between the artists and embodied the creative action. This understanding can be further developed by looking at a distributed model of cognition. In distributed cognition understanding and activity occur across multiple elements – people, environment/context, time and artefacts. The example typically given is one of landing an airplane: who or what is responsible for its safe arrival? The pilot? The co-pilot? The radio control tower personnel? The flight control dashboard with its range of sensors and controls? A distributed understanding of cognition argues that they all work together to land the plane, that the cognition is distributed across all of these elements [5].

Similarly in the works presented here, their constituting creative artefacts (drawings, stylus, website etc.) all work together to support the creative activity. Put another way, the creative activity was *distributed* across ourselves, our brushes, paper and the individual drawings we swapped in the co-drawing effort. Similarly, for a participant interacting with *Of me with me*, their creative activity and experience stretches out of them across the stylus to also include any images created as well as the website they are posted to and, of course, the software.

From the distributed cognition model it becomes clear that the various creative activities described here – ranging from wheelchair action painting through to co-drawing and the final interactive art system – all distribute the creativity around the participant. In this sense the artefacts and artworks also contribute to creative cognition; and they have worked together to inform this.

Furthermore, by viewing the creative process presented here from the perspective of distributed cognition, it becomes possible to see the software as a creative counterpart to the participant, or a conversationalist in a creative dialogue. This theoretical confirmation suggests the design approach taken here has merit. It is also a good starting point for considering what, if any, types of creativity that these situations can support? For

example it might be that in the first sketch using wheelchairs, the notion of what it means to draw and how one can draw was *transformed* by attaching paint rollers to the wheelchairs, i.e. that this facilitated *transformative creative* experience. In the second sketch process where drawings were handed back and forth, this creative conceptual space was explored and '*exploratory creativity'* was facilitated. The exploratory behavior led to a consideration of what else is possible? What are the limits of this? Or it may be that the final, interactive artwork *Of me with me* pushed these limits even further to the point of negating the collaborator's presence. By facilitating someone to draw collaboratively, yet not with another person, it can be considered a means to *transform* the creative drawing space.

This body of work and the final interactive art system *Of me with me* arguably have the potential to support a range of different creative experiences in participants. One key point here is that creative experiences lead one to think of what else might be possible: they can facilitate freedom. And freedom of expression is one means towards facilitating self-efficacy: independence and self-determinism (for example see [2, 9, 11, 12, 17, 35, 42]).

8.4. *Evaluation for future work*

Future work involves conducting evaluations to better understand the participants experience of the work, as well as creative emergent experience in general terms. Evaluating for emergent participant interaction has been conducted previously [49, 50] and a similar qualitative approach of participant observation and interviewing will be used here. Future concerns are gaining understanding of participant's perception of the creative value of their interactions. This is necessary since something must be valued in order to be considered creative. However, it is worth noting that participant and collaborator feedback has, to date, been positive. For example, collaborating artist Saunders described her intent to embed aspects of drawings created with this system into a print she was working on. One could infer from this that the imagery she made is valued and possibly creative.

Insight into any changes in how people understand drawing or collaborating is also sought. For example, it could be that *Of me with me* transforms understanding of what it means to draw or make marks. As discussed above, could these emergent creative experiences change one's understanding of what it means to draw or make marks? Could they prompt one to think of what other things might be possible and, in so doing, facilitate a sense of freedom? Put another way, can this emergent artistic visualization facilitate a creative activity and, by extension, a sense of independence and self-efficacy? It may be that by supporting creative expression and challenging the notion of what's possible, emergent interactive design has potential to facilitate self-efficacy in a participant.

A traditional understanding of designing for Human Computer Interaction (HCI) does not allow for ambiguous or creative interactions. Instead the traditional focus of HCI has been on routine, well defined or low level tasks [8, 19]. While some advents into complex

interactions such as ambiguous or open-ended interactions have been made [28, 29, 51] these are still few in number. Bødker's articulation of a 'third wave' of HCI overtly states a need to focus design on people's creative, emotional and non-work interactions but the design of such systems is still little understood [8]. Emergence in interactive art can provide some answers. As has been discussed, emergence is implicitly creative. Emergent and creative designs are a mechanism whereby we can expand the domain of HCI to more complex, personally satisfying and next generation, human computer interactions.

9. Summary

Emergence has been described and shown to facilitate creativity. The artwork presented has been facilitated through a complex sciences understanding of emergence, namely fractal theory. It demonstrates that while there remain debates across domains of emergence theory, there are still some common characteristics of emergence and these have the potential to inform design. Specifically, there is a combinatory creative potential for taking emergence theory from one domain to effect it in another. Similarly, as is the case here, emergence theory from one domain can be used to effect a characteristic of emergence i.e. creativity as it is understood in another domain. In this artwork emergence as it is understood in complex sciences and, particularly using a fractal theory, has been used to enable audience perception of emergent structures. This is an instance of perceptual emergence, the understanding of emergence held in the Design Research community.

Emergence may also hold potential for designing engaging artistic visualizations. Here the scaled and transformed copies of participant gestures are the 'parts' that interrelate to form an emergent, compositional 'whole' (as in Figure 1 and Figure 9 top right). At the same time, these parts are also the actual data. Similarly, the data is also a means whereby the parts are organized. Following the earlier discussion on engagement in interactive art, it may be that *direct visualization* has the potential to facilitate increased audience engagement, particularly through *attraction* and *relation.* This has been discussed as the design intention in *Of me with me*. Creative experiences, particularly the *transformative creative* experience of drawing collaboratively yet not with another person have also been discussed as extending the audience's understanding of what is possible and, as a result, increasing your sense of self. Future work can use evaluations, such as through observation and interview to gain better understanding of the how these design approaches affect people.

The interactive art system *Of me with me* has shown the potential of emergence for organization of data, directly, to enhance audience engagement. The discussion presented here also demonstrates a great potential for emergence in interactive artistic visualization to effect creative experience.

10. Acknowledgements

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