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What About Interaction Geography to Evaluate Physical Learning Spaces?

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Abstract This paper reviews and explores how interaction geography, a new approach to visualize people's interaction over space and time, extends current approaches to evaluate physical learning spaces. This chapter begins by reviewing representations produced using interaction geography to study visitor engagement and learning in a museum. In particular, this review illustrates *Mondrian Transcription*, a method to map people's movement and conversation over space and time, and the *Interaction Geography Slicer (IGS)*, a dynamic visualisation tool that supports new forms of interaction and multi-modal analysis. Subsequently, this chapter explores how interaction geography may advance the evaluation of physical learning spaces by providing dynamic information visualisation methods that support more expansive views of learning and the evaluation of the alignment between space and pedagogy. This chapter concludes by outlining significant limitations and next steps to expand interaction geography to evaluate physical learning spaces.

Introduction

Historically, the evaluation of physical learning spaces has relied on concepts and methods from professional design disciplines (e.g. architecture, urban planning) to assess how the physical design of space conditions the measureable learning performance of people. For example, post-occupancy evaluation (Zimring & Reizenstein, 1980; Zimmerman & Martin, 2001) is often used to evaluate how the physical structure of spaces (e.g. as represented through methods of space syntax or building information modelling) influences people's learning performance on standardised tests or "behavior performance scores" (Wineman, Peponis, & Dalton, 2006; Hillier, 2008; Peponis, 2005; see Cleveland & Fisher, 2014 for full review).

On one hand, this work continues to demonstrate that there are relations between the physical environment and learning despite "many sweeping claims about the

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possible effects of various aspects of learning spaces on student learning that are not substantiated empirically" (Tanner 2000 as cited in Blackmore et al. 2011, pg. 5; also see Imms, Cleveland & Fisher, 2014; Tanner, 2009). On the other hand, this work provides little explanation as to how or why these relations are observed in correlational analysis.

Recent research has defined three distinct areas that must be addressed to advance the evaluation of physical learning spaces. First, new research methods need to be developed that are "capable of controlling the complex variables inherent to space and education" (Imms & Byers, 2017). Second, concepts and methods used to evaluate physical space need to be better integrated with a broader understanding of learning theory (Ellis & Goodyear, 2018) to include, for example, social practice, and sociocultural theories of learning (Lave & Wenger, 1991; Cole, 1996). Third, research needs to develop ways to assess people's participation at a scale and in ways that support working with professional practitioners to study and design for the alignment between space and pedagogy (Cleveland & Fisher, 2014).

This chapter reviews and explores how interaction geography, a new approach to describe, represent, and interpret people's interaction over space and time (Shapiro et al. 2017), provides one way to address these needs and extend current approaches to evaluate physical learning spaces. This chapter begins by reviewing representations produced using interaction geography to study visitor engagement and learning in a museum. In particular, this review illustrates *Mondrian Transcription*, a method to map people's movement and conversation over space and time, and the *Interaction Geography Slicer (IGS)*, a dynamic visualisation tool that supports new forms of interaction and multi-modal analysis. Subsequently, this chapter explores how interaction geography may advance the evaluation of physical learning spaces by providing dynamic information visualisation methods that support more expansive views of learning and the evaluation of the alignment between space and pedagogy. This chapter concludes by outlining significant limitations and next steps to expand interaction geography to evaluate physical learning spaces.

Interaction Geography in a Museum

The following sequence of representations reviews interaction geography and in particular, methods of interaction geography that include Mondrian Transcription and the IGS as described by Shapiro et al. (2017). Though these representations use data from a museum context, this review intends to communicate the potential application of interaction geography more generally, to a variety of settings. Notably, these representations are complex and necessitate new ways of reading the physical environment, people's activity, and people's movement over space and time simultaneously. For high resolution/colour representations please see https://benrydal.com.

Figure 1 maps the movement of a six-year-old boy, Blake (blue path), and his sister's fiancé, Adhir (orange path), as they visit a museum gallery together. Also

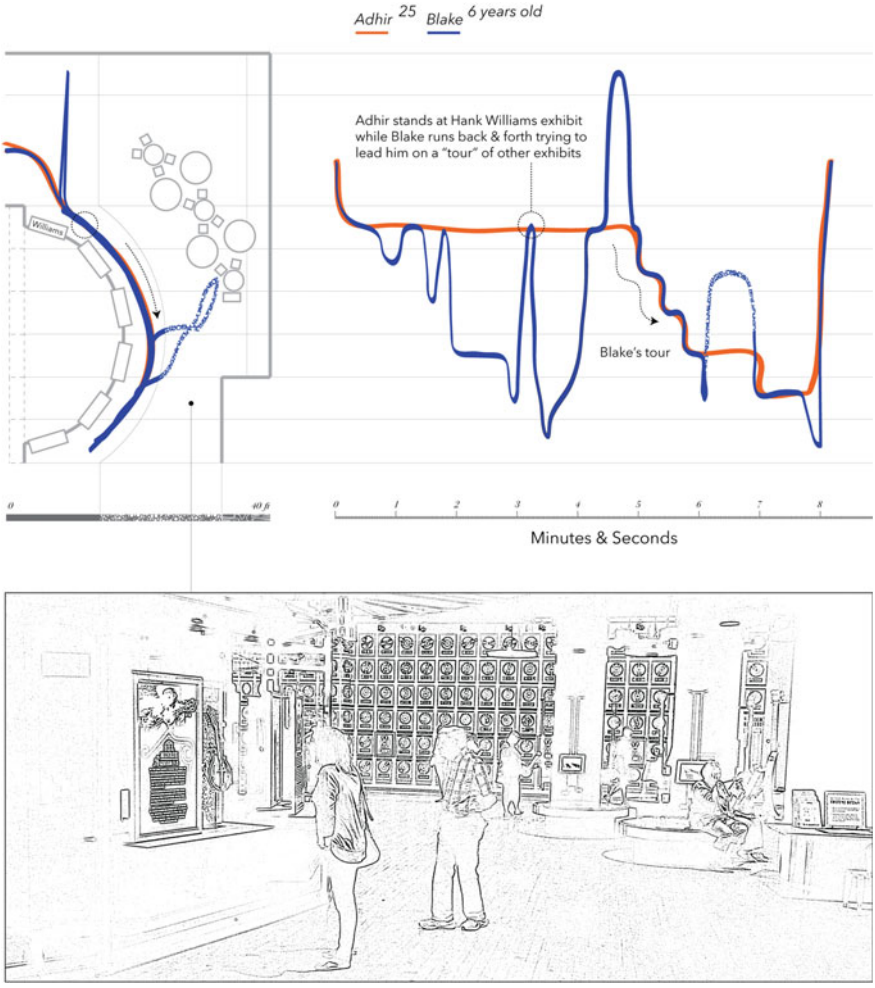

Fig. 1 Adhir and Blake's movement across a museum gallery space is shown over space and space-time. Copyright © by Ben Rydal Shapiro. Reprinted by permission

included in the figure is a rendering showing the gallery space from a point marked on the floor plan. The left of the figure or "floor plan view" shows their movement over a floor plan of the gallery space (i.e. looking down on the space). This view shows where Blake and Adhir go within the gallery space. The right, or "space-time view" (Hagerstrand, 1970) extends Blake and Adhir's movement on the floor plan horizontally over time. This view shows how they interact with exhibits and one another over time. For example, the space-time view shows that after entering the gallery space (top left of floor plan view and beginning of space-time view), Adhir and Blake walk together towards an exhibit about Hank Williams (marked on the floor plan). Subsequently, Adhir stands for almost 5 min at the Hank Williams

exhibit, as indicated by his horizontal orange path in the space-time view that extends from approximately minutes 0–5 and corresponds to the vertical position of the Hank Williams exhibit in the floor plan view. In the meantime, while Adhir is standing, Blake is moving quickly (apparently running) back and forth across the gallery space (i.e. across the semi-circle of exhibits on the floor plan) in multiple attempts to draw Adhir away from the Hank Williams exhibit. After four failed attempts, Blake finally succeeds in leading Adhir on a tour of other exhibits in the gallery, indicated by their intertwined paths from approximately minutes 5–6. The change in line pattern in Blake's path distinguishes between different horizontal areas of space on the floor plan providing some description of horizontal movement on the floor plan in the space-time view (this technique has limitations but becomes more relevant when more people are shown).

Figure 2 extends the previous figure. The figure is a screenshot from the IGS and illustrates Mondrian Transcription. Namely, the figure maps the movement and conversation of all five members of a family (called the "Bluegrass Family"), including Blake and Adhir but also Blake's brother Jeans (green), Blake's sister Lily (yellow), and Mae, referred to as "Mom" (purple, the mother of Blake, Jeans and Lily). The top half of the figure shows the family's movement and the bottom half shows their conversation in relation to their movement (i.e. the family's movement is shown in grey beneath their conversation to link the two halves of the figure). Conversation is transcribed and organised in a manner that draws from and extends conventions of conversation and interaction analysis (see Jordan & Henderson, 1995; Erickson, 2004; Kendon, 1990).

First, each turn at talk is shown as a coloured line to indicate which family member speaks that conversation turn (indentations indicate overlapping speech). Second, coloured lines of talk are gathered into boxes that group topically related sequences of conversation turns and movement (e.g. in this case, usually related to artefacts/musicians in this setting). Thus, in the space-time view, each box marks the start, duration, and end of a sequence. In the floor plan view, conversation turns and separate (in time) sequences accumulate within regions of gridded space–the box thickness in the floor plan view increases with each repeated sequence within a region of space. For example, the region of space around the Hank Williams exhibit has the largest number of conversation turns (as indicated by the many coloured lines of talk) and is enclosed by a dense box that reflects five separate (in time) sequences occurring at the Hank Williams exhibit. The highlighted sequence (i.e. readable conversation) in the space-time view expands the conversation turns of one particular sequence. This is a type of "operation" made possible by the IGS (i.e. in the IGS a user can hover over conversation lines to magnify/read conversation turns). In the figure, the grouping of these sequences is determined in one particular manner, but Mondrian Transcription allows conversation and movement to be grouped in a variety of ways and also potentially supports a variety of transcript conventions (e.g. to show the direction of speech).

This figure provides ways to interpret people's interaction and movement in relation to the physical environment. For example, the highlighted sequence in the figure from approximately minutes 4–5 in the space-time view encompasses a complex

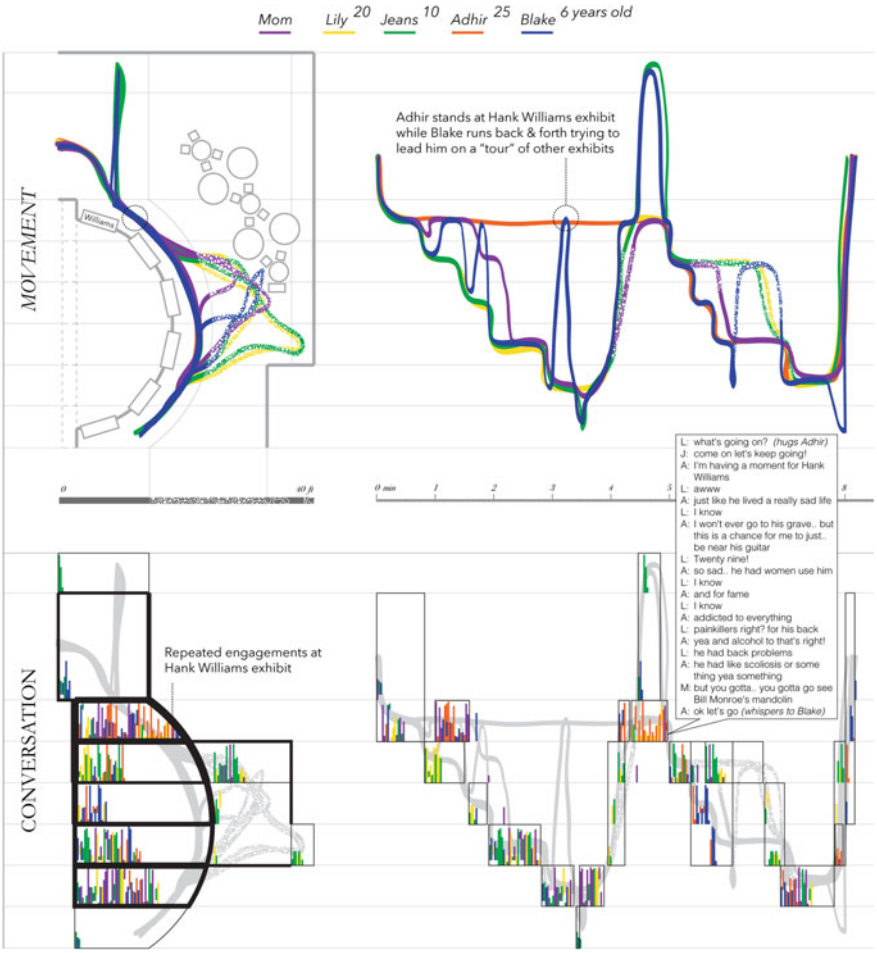

Fig. 2 Mondrian transcript of the Bluegrass Family's interaction geography. Copyright © by Ben Rydal Shapiro. Reprinted by permission

mesh of activity around the Hank Williams exhibit. As described by Shapiro et al. (2017), reading this sequence of activity in relation to the rest of the figure shows how:

(1) Lily soothes the emotions of Adhir (her fiancé) by hugging and consoling him as he compares the Hank Williams exhibit to a "grave" (in line 8).
(2) Jeans gives Lily and Adhir privacy by leading a frustrated Blake away from the Hank Williams exhibit (the extension of their movement paths upwards in the floor plan and space-time views indicating their movement away from the exhibit).

(3) Blake and Jeans re-join Lily and Adhir as Adhir continues to share his own account of Hank William's painful life.
(4) Mae (Mom), who has been standing near Adhir and Lily and observing her family's interaction, helps Blake lead Adhir on a tour of other exhibits by saying to Adhir, "but you gotta.. you gotta go see Bill Monroe's mandolin" (in lines 22–23).
(5) Evidently fully aware of Blake's ongoing project to lead a tour, Adhir whispers to Blake, "ok let's go" and they move forward together to the next Bluegrass artist (at the end of the highlighted conversation).

In other words, reading these interpretations in relation to the rest of the figure reveal phenomena (e.g. Blake's tour and Adhir's persistent engagement with the Hank Williams exhibit) not visible without methods of interaction geography. These interpretations require multi-scalar ways to (a) analyse structural properties of settings alongside visual patterns of people's conversation and movement, (b) read individual conversation turns and situate these conversation turns with respect to simultaneous conversations occurring in different parts of a museum gallery space, and (c) not communicated here but possible within the IGS, to watch/listen to video/audio from the perspective of each family member gathered as part of this research (i.e. Mondrian Transcription/the IGS syncs multi-perspective audio and video if available to these visualisations).

Figures 3 and 4 are screenshots from the IGS displayed in a small multiple format (Tufte, 1990). Figure 3 shows continuous movement for each family/group whereas Fig. 4 shows "personal curation" or traces of movement where visitors are using

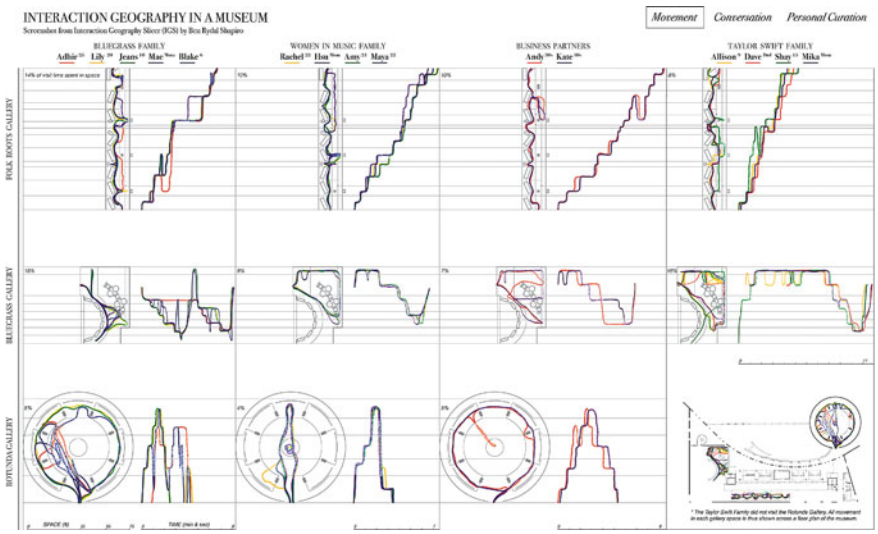

Fig. 3 Screenshot from IGS showing movement of 4 visitor groups in 3 gallery spaces. Copyright © by Ben Rydal Shapiro. Reprinted by permission

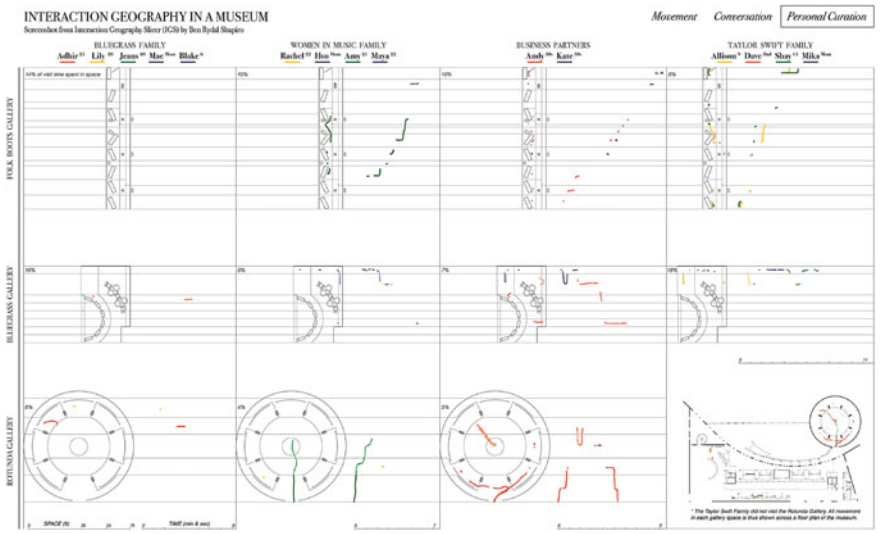

Fig. 4 Screenshot from IGS showing personal curation of 4 visitor groups in 3 gallery spaces. Copyright © by Ben Rydal Shapiro. Reprinted by permission

personal information devices and/or social media to collect, edit, and/or share content from the museum. Columns in each figure distinguish each visitor group/family while rows indicate different gallery spaces. All displayed information across these figures is set to the same scales. Since the "Taylor Swift Family" did not visit the Rotunda Gallery, all visitor groups' movement and personal curation is combined on a larger floor plan drawing of the entire museum.

Figures 3 and 4 illustrate the comparative possibilities of interaction geography. In this setting these comparative possibilities support studying how individual visitors and groups of visitors align with cultural heritage content. For instance, it is clear (for those who know these spaces such as museum professionals working at this museum) that the "Women in Music Family" (2nd column) interacts in a variety of ways with exhibits and gallery spaces that feature female artists while the Bluegrass Family (1st column) exhibits very different types of interactions around exhibits that feature early Country and Bluegrass artists. Likewise, these figures can be used to identify heightened moments of potential interest and engagement (e.g. young children's rapid/sharp movements in space-time). Using the IGS in this setting, these moments can be unpacked to understand, for example both how parents structure young children's conversation to learn (the primary focus of learning research in museums) and also how young children use their families as interpretive resources for learning through their expressive movements and conversations. For example, closer analysis of Blake's movement and conversation in the space-time view during minutes 3–5 while visiting the Rotunda gallery (column 1 and row 3) illustrates how, Blake first failed to get an answer to a question he posed to Adhir as to who co-starred in the 1970s action/comedy film Smokey and the Bandit. Immediately

afterward, Blake ran to another gallery space to find and get the correct answer from his brother Jeans. Subsequently, Blake then raced back to re-join Adhir in the Rotunda Gallery in order to inform Adhir that it was Jerry Reed, a Grammy-winner country artist, that co-starred in the film.

Extending Physical Learning Space Evaluation

From Static Representations to Interactive Visualisations. The previous figures illustrate how interaction geography uses Mondrian Transcription to integrate representations from a variety of disciplines. These representations include floor plans, transcripts of conversation, and personal time geography (Hagerstrand, 1970). As a result, new types of multi-scalar analyses are possible that link detailed analyses of people's interaction at locations in the physical environment with analyses of people's interaction as they move across the physical environment.

The previous figures and analysis also provide a glimpse of how the IGS supports dynamic interaction with these representations. For example, in this case, analysis of the previous figures begins to convey how the IGS allows researchers and practitioners (e.g. museum professionals) to select sequences of movement and conversation for closer analysis, to watch audio and video from the perspective of each family member, and to re-scale space or time in order to study phenomena at different scales while conducting new types of comparative analysis.

Historically, representations used to evaluate physical learning spaces have been static (i.e. providing snapshots of space) and often unidimensional (i.e. only focusing on space and not people's interaction or movement over space and time). Interaction geography illustrates the potential and new possibilities to use dynamic visualisations as opposed to static representations in order to evaluate physical learning spaces.

Incorporating Broader Views of Learning. Current approaches to the evaluation of physical learning spaces typically operate from a positivist stance. For example, in an informal setting such as a museum, such a stance dictates both a model of a museum visitor as a relatively passive consumer of intended exhibit design as well as evaluation methods that focus on how physical structures of gallery spaces support visitors' acquisition of the intended design and narrative of exhibits produced by museum curators and designers. Such a stance provides valuable information to inform future design. However, such a stance often ignores people's activity and how people produce and pursue their own learning in ways that are very different from how people acquire intended design/curricula.

Interaction geography provides concepts and methods to describe people's interaction (e.g. pace of talk or movement, social media use) at a scale that maintains a focus on the physical design of space. In the figures above, one result is the ability to characterise Blake's efforts to lead Adhir on a tour. This characterisation provides one vivid example of how children's seemingly erratic movement patterns, which current evaluation methods might either miss entirely or suggest detract from Blake's and

his family's ability to acquire knowledge about exhibits, reflect Blake's very intentional efforts to pursue his own interest-driven learning: In this case by teaching other family members about the cultural heritage content of a museum gallery space. More generally, interaction geography provides a means to study how people's activity responds to the physical design of spaces (and changes made to these spaces) over varying periods of time (e.g. potentially over hours, days, and longer periods of time). Studying changes in activity or participation is central to theories of learning that study how learning is distributed across people, tools, and physical learning environments (Cole, 1996; Gutiérrez, Morales, & Martinez, 2009; Vygotsky, 1980) and how people learn through participation in socially and culturally organised practices of a community (Lave & Wenger, 1991). Put differently, interaction geography supports evaluating physical learning spaces not only with respect to how they may influence learners' performance on standardised tests or behaviour performance scores but also with respect to how they support or do not support social contexts for learning.

Incorporating broader theories of learning into the evaluation of physical learning spaces encourages new research that may be necessary to illustrate how and why there appears to be a relation between the physical design of space and learning. For example, in classroom and school settings, such work might include assessing how physical space shapes the embodied production of identity (Leander, 2002) or structures joint participation in specific disciplinary practices such as writing (Rowe, 2008) or how physical proximity influences teachers' interactions with peers about teaching (Spillane, Shirrel, & Sweet, 2017). Alternatively, in natural or urban environments such work might include studying how people's personal mobility is both the means and content for learning or describing how people "make places" to pursue their own interest-driven learning as they move through physical spaces rich with meaning potential (Hall, Taylor, & Marin, 2017; Marin, 2013).

Evaluating the Alignment of Space and Pedagogy. As mentioned previously, interaction geography describes people's interaction at a scale that maintains a focus on the physical design of space. As a result, it supports studying the alignment between space and pedagogy in new ways (Cleveland & Fisher, 2014). For example, consider the application of interaction geography in classroom settings to ask and answer questions about the physical design of learning spaces that are challenging to address with current methodological approaches. These questions include: How do teachers use or not use particular areas of space over single or multiple lessons? When and where do students have access to particular types of instruction or pedagogical interactions? How does students' and teachers' movement and conversation reveal types of empowering and disempowering pedagogies that are built into the physical design of certain classrooms (Monahan, 2002, 2005; Cleveland, 2009).

Furthermore, current research emphasises that evaluating the alignment of space and pedagogy necessitates close collaboration between researchers and professional practitioners (e.g. teachers, museum professionals) working in the spaces being studied. Interaction geography provides a highly visual method that may support this collaboration in ways that can inform future design. For example, the previous figures were utilised in collaboration with museum professionals at one particular museum.

Making visitor interaction and personal curation visible for these professionals had a significant impact on this museum. In particular, studying the previous figures contributed to the redesign of one museum gallery space and supported challenging interdepartmental and crossdisciplinary conversations between museum curators, educators, and architects who held very different beliefs as to what makes a successful gallery space. Likewise, prior to viewing these visualisations, museum professionals at this museum did not realise visitors used social media while in their gallery spaces and thus, had not developed educational programming or marketing initiatives that encouraged or supported visitor's personal curation. In response to these visualisations, this museum developed social media policies (e.g. hashtag/indexing mechanisms) that encouraged the use of personal curation to learn and teach others about museum content in ways that also advanced the museums' marketing and educational goals. More recently, this museum has begun to explore more personalised ways to support visitors' personal curation, for example, by supporting teachers to use museum content to develop their online teaching profiles (see Shapiro & Hall, 2018).

Limitations and Next Steps

In summary, this chapter reviewed and explored how interaction geography, a new approach to describe, represent and interpret people's interaction over space and time, extends current approaches to the evaluation of physical learning spaces. This chapter concludes by discussing some of the primary limitations in this early work that must be addressed to expand the use of interaction geography to evaluate physical learning spaces.

First, as demonstrated in this chapter, reading visualisations produced by interaction geography is challenging and necessitates new types of interdisciplinary thinking as well as close collaboration with practitioners who are in the best position to interpret these visualisations. Future research will need to explore a variety of questions related to this challenge. For instance, these questions include: What resources do different disciplines and practitioners working in different disciplines offer to read representations of interaction geography? What insights do different disciplines and these practitioners offer to interpret these representations from a learning perspective? Using Blake's tour as a starting point, what is a taxonomy of interaction geography patterns that can be read to study productive or unproductive alignments between space and pedagogy in different types of physical learning spaces?

Second, questions regarding how to generalise methods of interaction geography in an ethically informed manner are only beginning to be explored. For example, recent work has applied the IGS to visualise and discuss New York City's controversial Stop-And-Frisk Program (Shapiro & Pearman 2017). However, future research will need to explore a variety of questions that necessitate further technical/computational development of the methods/software illustrated in this chapter. These questions include: How can researchers, designers, and practitioners working

in a variety of settings customise and use these methods to evaluate physical learning spaces? What types of visual analytics and natural language processing need to be incorporated into the IGS to advance its utility? What settings and institutional contexts are these methods ethically and not ethically appropriate?

Third, interaction geography is a very new approach that is only beginning to be applied beyond the museum setting described in this chapter. Future research will need to test and assess the usefulness of interaction geography in a variety of settings. In particular, future research will need to conduct research to develop comparative questions and analyses. For example, future research needs to explore questions such as what are productive spatial and temporal scales or boundaries of settings that enable comparative work based on interaction geography? What types of mappings (e.g. of people, artefacts, sound) does interaction geography support? What types of physical spaces is interaction geography best (and least) suited?

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