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Routledge
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Affordances and distributed cognition in museum exhibitions

Marianne Achiam[a]*, Michael May[a] and Martha Marandino[b]

[a]Department of Science Education, University of Copenhagen, Øster Voldgade 3, 1350 Copenhagen, Denmark; [b]Faculty of Education, University of São Paulo, Avenida de Universidade 308, Cep. 05508-040, Cidade Universitária, São Paulo, Brazil

Exhibitions are the primary medium for the public communication of science in museums. Recently, there has been an interest in explaining the educational mechanisms of exhibitions in terms of meaning making, interaction and space; however these concepts have not yet been integrated into one consistent framework. Here, we invoke the notions of *affordance* and *distributed cognition* to explain in a coherent way how visitors interact with exhibits and exhibit spaces and make meaning from those interactions, and we exemplify our points using observations of twelve visitors to exhibits at a natural history museum. We show how differences in exhibit characteristics give rise to differences in the interpretive strategies used by visitors in their meaning-making process, and conclude by discussing how the notions of affordance and distributed cognition can be used in an exhibit design perspective.

Keywords: museum; exhibit design; affordance; distributed cognition; visitor experience; diorama; discovery room

Science centres, natural history museums and science and technology museums (in the following: 'museums') host a broad spectrum of educational offers, but exhibitions remain their primary medium for the public dissemination of science. The educational mechanism of exhibitions and their constituent parts, exhibits, has been described in several studies; common to these descriptions is the assertion that visitors' experiences in exhibitions can be conceptualised on several levels, and that these levels are characterised by an increasing degree of abstraction (Allen 2004; Feher 1990; Mortensen 2011). At the most basic level, the visitor encounters an individual exhibit, and that exhibit presents the visitor with one or more allowable actions or tasks. At the next level, the visitor interacts with the exhibit using their chosen techniques or ways of manipulation. At the third level, the visitor begins to generate an explanation of the phenomenon shown in the exhibit by comparing the outcomes of their interactions with their expectations. And finally, at the fourth level, the visitor begins to generalise their ideas by including other, related exhibits.

This pattern of interaction raises a number of issues that are pertinent to exhibit design. How does an exhibit attract and hold a visitor's attention without the intervention of a human mediator? How does a visitor, who has never seen a particular exhibit before, know what to do with it? And how does the visitor make sense of that interaction?

*Corresponding author. Email: achiam@ind.ku.dk

Meaning making, interactions and exhibition spaces

In recent discussions of exhibition design there has been a strong focus on *meaning making*, the role of *visitor interactions* with exhibits and the role of *exhibition space*. The theoretical support for this focus on meaning, interaction and space has to some extent been found in the utilisation of concepts borrowed from cognitive science, design theory (in product design and architectural design) and semiotics.

One example is the concept of narrative that creates an opportunity to rethink museum and exhibition design as an integral design of 'narrative environments' (Hanks, Hale, and Macleod 2012) or 'narrative spaces' (Locker 2011), where objects and spaces become part of a 'process of storytelling' (Hanks, Hale, and Macleod 2012, ix). We are very much in accordance with this integral approach, but the question is how narratives can accomplish this unity of architectural space, exhibition design, and museum artefacts and how these narratives can actually be articulated within the meaning making of visitors. To answer questions like these we have to understand the cognitive and semiotic dimensions of meaning making. Narrative meaning has to be constructed from more elementary forms of meaning making such as the recognition of the kinds of activities objects allow for as well as their lexical meaning, as we will argue in this paper. The unique focus on narratives is accordingly too restricted, since we really need to understand all levels of meaning involved in meaning making in the museum context – from the point of view of curators and designers, as well as from the point of view of museum visitors.

Another concept that has recently been invoked to understand exhibition design is that of *affordance*. We shall examine the concept more closely in the following; here, however, we note that affordance has been used to analyse design problems of interactive exhibits in science centres (Allen and Gutwill 2004), but also as part of the narrative framework for understanding meaning making and supporting collaboration across different domains and practices such as architectural design, landscape design and exhibition design (Austin 2012). The recent publication, *Museums and Silent Objects* (Monti and Keene 2013), is at the same time a case study of the Egyptian collections of the British Museum and an ambitious attempt to theoretically integrate elements of cognitive science, design theory and architectural theory into a framework for exhibition design. It is however again rather restricted in its use of key concepts: the concept of affordance is implicated, but it is applied indirectly through the concept of 'usability' (which is theoretically grounded in the theory of affordances, cf. Norman 1988), without a critical analysis of its application to the museum context (Monti and Keene 2013, 61–65).

A third approach that has been taken recently to understand exhibitions is the analysis of exhibition space, where spatial structures are analysed at the behavioural level of the *space syntax* of visitor movements. Space syntax studies, however, disregard the 'content' of the space (Monti and Keene 2013, 27–33), as well as the intentions of the visitors and their meaningful relation to artefacts and places. All in all we will argue that recent museum studies could benefit from a more systematic and critical use of concepts borrowed from cognitive science, design theory and semiotics. With regard to semiotics, some authors identify a relevant counter-reaction to earlier 'post-modern' uses of French semiology and philosophy with a bias towards textual meaning to account for the recent focus on materiality and embodiment (Hale 2012, 193), but this counter-reaction is in full alignment with the (cognitive) approach to semiotics proposed below.

What are affordances?

The original concept of affordance was formulated by J.J. Gibson in his theory of ecological perception (Gibson [1979] 1986), where it refers to the physical-geometric properties of objects and places within an animal habitat *taken in reference to* a particular species and its behaviour: 'The affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill' (Gibson [1979] 1986, 127). For many terrestrial animals the firm horizontal ground of a flat landscape will afford e.g. standing, walking and running. However, the affordances are not the properties as such (e.g. firmness, flatness), but their *relation* to a specific species, and thereby the action possibilities these properties provide. On the other hand, affordances are not 'in the mind' and are not dependent upon their being perceived or not. They are objectively present as opportunities for action given the relation between a species and its environmental niche.

The extension of the concept to the world of design, *design affordance*, was initiated in the famous book, *The Design of Everyday Things*, by Donald Norman (1988). Norman later lamented that the design community to some extent had misunderstood his use of the concept. He was mainly concerned with *perceived affordances* rather than the real 'physical' affordances (Norman 1999). This conceptual split between perceived and real affordances arises when the concept is extended from natural to cultural objects as a consequence of the need to account for 'bad design' and the discrepancy that might exist between design intentions and the conceptions and actions of ordinary users. Indeed, it is the concept of perceived affordance that has been used, sometimes implicitly, in a number of the studies that apply it to a museum setting (Allen 2005; Mortensen, Rudloff, and Vestergaard 2012; Reich and Parkes 2005; Rowe 2002; Monti and Keene 2013).

Meanwhile, the need to account for the possible discrepancy between a designer's intentions and a user's realised interactions led William Gaver to introduce different variants of the concept of affordance that seem contradictory from the point of view of Gibson: besides the affordances that are real (and usually recognised as such), Gaver suggests that we should acknowledge 'false affordances', i.e. affordances that appear as such, but are not real, as well as 'hidden affordances', i.e. affordances that are real, but do not appear as such (Gaver 1991). An example of a false affordance mentioned among product designers is the 'Close door' button in elevators that is arguably (in some cases) installed only to give passengers a sense of control, but without actually doing anything. From Norman's point of view this would be an example of a cultural convention and an expectation (that is being violated), i.e. it is not a (false) affordance but a (broken) convention.

To illustrate this point in the context of a museum exhibit we might use the following simple interactive exhibit from the Natural History Museum in Helsinki (Figure 1A). A schematic drawing of a cow and four bone samples are shown and the visitor is asked: What part of the cow? Below the bone samples four lids can be seen. Let us imagine, for the sake of the argument, that there is no answer to the question under the respective lids! This could be called a false affordance, but we would again argue that it would be better described as a broken convention and a violation of visitor's expectations of the interaction. Adults and children will usually attempt to guess the answer to the cow bone question first and then open the lid to get the answer, not because there is an affordance to do so, but because this visual question-answer structure is familiar to them from memory games. There actually is an affordance involved, but this is the lid knob that affords the

Figure 1.   (A) Interactive cow bone exhibit: What part of the cow? (The answer is under the lid). Natural History Museum, Helsinki. Photograph courtesy of Michael May. (B) Sheep skeleton interactive exhibit, Natural History Museum, Aarhus. Photograph courtesy of Natural History Museum, Aarhus.

action of opening the lid. Knowing that the answer is below the lid is not an affordance, but a cultural convention and expectation of the typical visitor.

Figure 1B shows a schematic drawing of a sheep and a full collection of bones that would initially be found in the tray to the left in the interactive exhibit. The visitor is here invited to 'build your own sheep' from the bone collection. To support this action, the large sheep profile spatially fits the potential sheep skeleton. This spatial correspondence of bones and sheep profile is a physical-geometric affordance and so is the 'graspability' of the individual bones. There is, however, also in this case, a level of knowledge present that rests on a cultural convention: the recognition that the relevant task is like a puzzle.

As a variant example of a hidden affordance we might consider one of the cases described by Allen and Gutwill (2004). The Light Island exhibit allows visitors to experiment with light in a number of ways, including reflection, refraction and colour mixing by using a number of connected devices. The multiple interactive possibilities with no apparent priority seem to mask the real affordance. There are too many combinations of actions possible, and furthermore there is no clear output area, where an expected outcome can be observed. In this example the affordance for exploring different light phenomena is really present in the exhibit. The design problem might be better described as a lack of constraint on the interaction: to be useful, the visitor needs a limited set of interactive possibilities or a least a sequential priority of tasks for exploring them, and this is also the redesign suggested (Allen and Gutwill 2004, 210).

Beyond exhibit design the concept of affordance has also been extended to the 'information spaces' of museum foyers, how visitors are guided and constrained by different *perceived affordances* and how these seem to comply with different user 'needs' (Mortensen, Rudloff, and Vestergaard 2012). The important point, however, is that affordances – perceived or not – should never be misunderstood as a property of 'ideas' or other mental phenomena. Physical as well as cognitive affordances always refer to our relation to features of situations in which we might find ourselves. Different situations, however, have different constraints on actions and this is one reason why affordance might change from time to time or from one place to another. Indeed, this was the discovery of the Gestalt psychologist Kurt Lewin, who formulated the basic concept of affordance prior to Gibson.

As a soldier in World War I, Lewin noticed how objects of a landscape had a different value for him as a soldier than they would have, for example, for a farmer or a wayfarer in peacetime. A house for the soldier in wartime situations might suggest a danger zone or a place of protection, whereas the same house for the farmer in peacetime would suggest a shelter and a home. Lewin said that the objects seem to have a 'suggestive character' (*Aufforderungscharakter*) (Lewin [1917] 2009), but that this suggestive character could change with the situation. It might be better to talk about features of situations than properties of objects (Chemero 2003). This does not imply that it is a mental phenomenon: a house really does support all the action opportunities mentioned, but changing situations impose different constraints on how these possibilities can be perceived and utilised. Objects seem to 'suggest' different actions to us, because of the way we relate to them in different situations. As argued by Carl Knappett in the context of archaeology and studies of material culture, we need a *situated semiotics* combining affordance theory and semiotics, if we are to understand artefacts in their form and function, as well as, their meaning (Knappett 2012).

To understand the affordance concept in a museum context, let us use an example from the Darwin exhibition at the Natural History Museum of Denmark (Figure 2A). At first the visitor might look at this exhibit and find it rather dull. It is a collection of apparently similar bullfinches and no particular actions seem to be supported – other than observing. On a closer look, however, the visitor might notice small differences between the finches and perhaps recall the importance of variation in the theory of evolution proposed by Charles Darwin. These thoughts will be supported further if the visitor notices that this exhibit is in fact a part of a *cluster* of exhibits (Figure 2B) demonstrating species variation. The bullfinch exhibit is juxtaposed to an exhibit showing the gradual adaptation of 'Darwin's moth', the white peppered moth species that turned black over a few generations thus enabling the moth to blend in with the black soot-covered trees of the industrial revolution. Viewing the cluster as a whole and by associating it with the theme of species, variation will therefore afford *comparison* as well as *generalisation*, and although these thoughts are not actions in the usual sense, we can argue that the cluster engages visitors in a way that *cognitively affords* reflection and discovery. Some
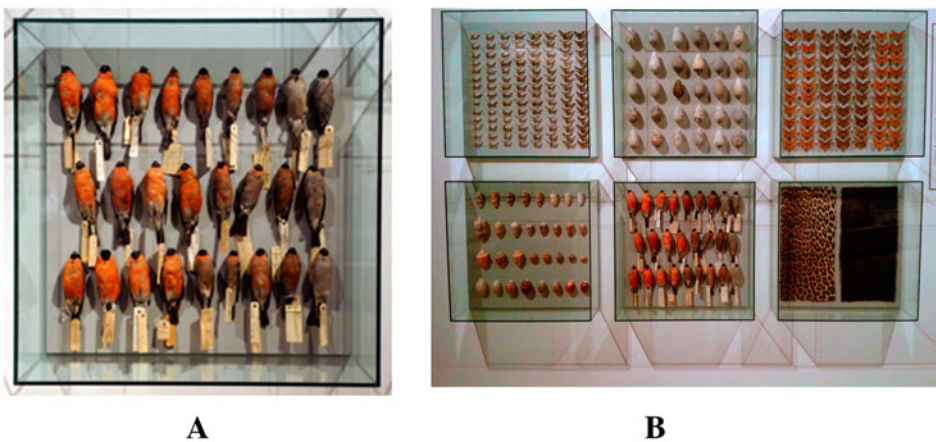

A   **B**

Figure 2. (A) An exhibit of bullfinch variation at the Evolution exhibition, Natural History Museum of Denmark. (B) The exhibit cluster that includes the bullfinch exhibit, and shows variation in five additional species. Photographs courtesy of Marianne Achiam.

prior knowledge about evolutionary biology will be necessary in order for this reflection and discovery to be linked to the examples of Darwin's observations on his voyages and to his proposed theory of evolution. This prerequisite prior knowledge is thus a constraint on the situation, if we assume the intent is for the visitor to meaningfully create a link between the phenomenon of species variation and Darwin's ideas.

What is distributed cognition?

The interplay of affordances arising from features of the situation and the abilities and constraints brought to the situation by the human participants (i.e. the visitors), is described in the proposed integration of affordance theory and distributed cognition. According to Zhang and Patel, 'distributed cognition is a scientific discipline that is concerned with how cognitive activity is distributed across internal human minds, external cognitive artefacts, and groups of people and how it is distributed across space and time' (Zhang and Patel 2006). Knowledge and information is not only 'in the mind' but is equally 'out there' embedded in and through signs, tools and artefacts (cf. Jakobsson and Davidsson 2012). Through the external representations we not only off-load and simplify the tasks we have to perform 'in the mind', but we are thereby also able to share and communicate knowledge and information by making it visible to others – or, to restate it in more general terms, by making it tangible to others in some sensory modality. In this way there is an intimate link between affordances of a situation and the balance between external and internal information. The integrated theory furthermore explains how affordances and constraints are intimately related (Figure 3). The external and internal 'representational spaces' combine to form an 'affordance space'. Affordances result from a relation between a living agent (with an internal 'representational space') and its environment within a particular situation (the 'external space').
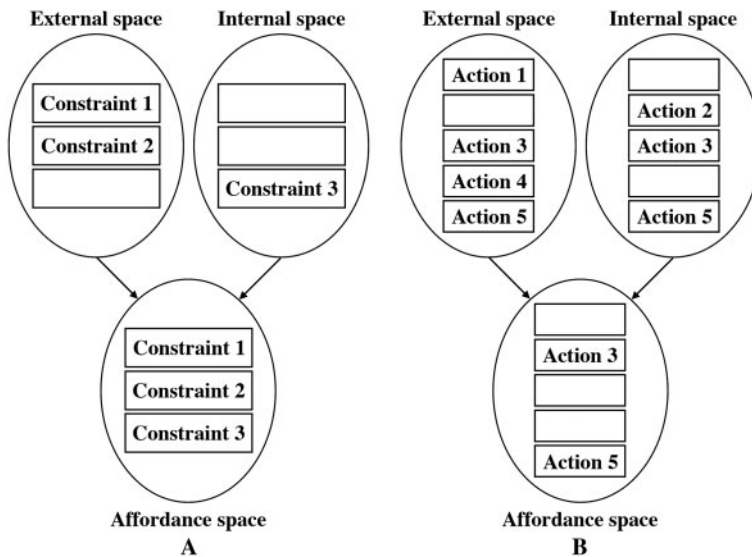

Figure 3. The two complementary perspectives on affordances and constraints. (A) The affordance space is defined by the disjunction of internal and external constraints. (B) The affordance space is defined by the conjunction of internal and external actions. Redrawn from Zhang & Patel (2006).

The affordance space can now be described from two complementary perspectives. We can focus on the *constraints* provided by either the situation or the agents in which case constraints are simply added in the affordance space, i.e. constraints are either external or internal. Alternatively we can focus on the *possible actions*. In the latter case there has to be a conjunction, i.e. 'allowable actions' have to be possible externally as well as internally.

From the point of view of the exhibition designer this means that one must know the abilities and constraints that visitors might bring to an exhibition, as well as, the constraints imposed by the exhibition space and its exhibits. In so far as visitors cannot be assumed, for example, to be familiar with the importance of variation for Darwin's discovery of the mechanism of evolution by natural selection, then a cluster of exhibits simply *showing* cases of this variation will not in itself provide a cognitive affordance for understanding this discovery. Visitors will have to provide the information and knowledge that is not supported externally in the exhibition. One design alternative is therefore to shift the balance of distributed cognition towards providing more knowledge and information externally and thereby increasing the probability that the exhibition will afford, in the words of Jakobsson and Davidsson 2012, the visitor's appropriation of the mediational potential of the exhibit cluster thereby meaningfully constructing notions of the role of variation in natural selection. Although the concept of distributed cognition is seldom found in analyses of exhibition design, it plays a key role in studies of material culture and specifically within *cognitive archaeology* (Sutton 2008).

Having outlined the notions of affordance and distributed cognition, we proceed now by illustrating how they can be applied using observations of museum visitors interacting with and interpreting exhibits in a natural history museum. Although our main proposition here is theoretical, we include these empirical data to describe and illustrate our points. By showing how the notions of affordance and distributed cognition can be applied in real life and by discussing the implications of the notions for exhibit design, we hope to contribute to the toolbox of museum researchers and designers alike by providing them with tools to analyse how and why exhibits work and, perhaps more importantly, how and why they do not.

Method

Data collection

The present account utilises data from visitors to the Natural History Museum of Denmark in Copenhagen, at two dioramas and two specimens in a discovery room, respectively. The first diorama included here represents a summer day in a Danish wood in the Atlantic period, about 7000 years ago. It contains a number of taxidermied specimens that are characteristic of the contemporary fauna, including a prominently located wild boar (*Sus scrofa*). The boar is standing among the trunks and foliage of deciduous trees, and faces a clearing where a lynx (*Lynx lynx*) is lying. In the background, a coastline is visible through the trees. The second diorama represents a summer day in a modern Danish beech forest, and features a prominently placed roe deer (*Capreolus capreolus*) with two lambs. The roe deer are grouped in a small clearing in the beech forest, surrounded by tree trunks and foliage. One lamb is nursing; the other is lying on the ground. Both dioramas have labels with illustrations of the animals they contain as well as their common and Latin names. The two dioramas are part of an exhibition about

Figure 4.   One of the investigated dioramas at the Natural History Museum of Denmark: A modern Danish beech wood forest. Photograph courtesy of Marianne Achiam.

the succession of flora and fauna in Denmark from the last ice age (about 12000 years ago) until today. Both dioramas are thus also equipped with longer texts indicating the period and its climatic characteristics. The beech forest diorama is shown in Figure 4.

The discovery room (a visitor-oriented, hands-on space with access to objects that are otherwise off-limits) features a number of taxidermied animals, preserved specimens, skulls, teeth and bones, nature and science books and microscopes. The objects are placed on open shelving units, giving visitors the opportunity to handle and examine them. The objects are not labelled, and apart from signs indicating that touching is allowed, there is no other signage in the room. In the present study, visitors were directed to pay attention to the taxidermied wild boar and the taxidermied roe deer on display there. The discovery room is shown in Figure 5.

Data were collected in 2011 and 2012. Adult visitors to the museum were directed either to the two dioramas or to the discovery room and asked to *think aloud* (van Someren, Barnard, and Sandberg 1994) during their interactions with the exhibits or specimens. A simple verbalisation process was assumed, yielding an objective reflection of the visitor's thought processes (Tulley and Lucas 1991). The visitors were observed during their interactions in order to take note of gestures and expressions (cf. Rowe and Bachman 2012). We did not attempt to solicit justifications for their thoughts, nor did we impose tasks upon them that would monopolise their attention during their think aloud process (cf. Dufresne-Tassé et al. 1998). The visitors' vocalisations were recorded on a digital recorder, and subsequently transcribed verbatim and translated into English. A total of twelve visitors were observed and recorded: four women and two men at the two dioramas, and three women and three men at the two specimens in the discovery room.

Figure 5.   The discovery room at the Natural History Museum of Denmark. Photograph courtesy of Marianne Achiam.

The visitors were numbered D1 through 6 (for diorama) and R1 through 6 (for discovery room), respectively.

Procedure

Our intent with the data analysis was to identify the actions allowed by the two different exhibit genres and perceived and acted upon by the museum visitors. This analysis took place in three steps. First, the transcriptions of the visitors' vocalisations were carefully read and re-read, with due attention to the observer's field notes. Then, instances of visitors' perception of an allowed action were identified as such. Consider the following example, in which visitor D5 at the beech wood diorama notices a model of an animal on the floor of the diorama:

D5: Maybe that's a slug over there. Let's see what it says here (reads label).

In this case, the model of the slug (*Arion ater*) in conjunction with the visitor's knowledge of what slugs look like afford a tentative identification of the animal, although a more definite identification can only be made with the constraint of the diorama's text label, which is correctly interpreted by visitor D5 to list the species present in the exhibit. By process of elimination it can thus be determined that the model is, in fact, a representation of a slug. In this example, the slug model in the diorama, the diorama label and the visitor comprise a distributed cognition *system* that determines the construction of information.

We identified all such instances of allowed and acted-upon actions in the transcriptions. In the final step of the analysis, we divided them into interactions at a basic level (location and identification) and at a higher level (more contextualised meaning making, e.g. constructing a narrative). In the following, we exemplify our findings, first for the dioramas and then for the discovery room specimens.

Exemplifying affordances and distributed cognition

The dioramas: basic levels of meaning and interaction

At a basic level, the relation between the visitor and the features of the diorama allows the action of looking. This is evident in the think aloud protocols, as evidenced by the following excerpt:

> D3: Well, when looking at this, first of all I see the two animals, and I'm looking at the scene, if I can see any other animals.

The visitors seem to focus on finding the animals. From the point of view of constraints and affordances this (imagined) task is in fact afforded by the diorama; some animals might be hidden by vegetation or only visible from a particular point of view, and the distribution of attention will first direct visitors to focus on animals in the foreground and overlook animals present in the background:

> D1: …then I try to find the animals, and, um, it was a little bit easier in this [diorama], except for the bird. I had to go down on my knees to find the bird over there, but, well, that's how it is, nature.

These activities contribute to a sense of a task of 'finding out' in the double meaning of locating the animals in the scene and identifying them as members of a species. Here it is an important constraint of the diorama that the information about location and species is not supported by representations directly in the scene, but on graphical signs external to the visual scene, since this creates a puzzle for the viewer and the opportunity to participate in (the imagined task of) finding the animals. This is an affordance created for visitors through the constraint of not explaining directly where the animals are:

> D3: Well, when looking at this, first of all I see the two animals, and I'm looking at the scene, if I can see any other animals. Then, I go closer to the [text panel] and I read that there should be, um, well, two animals and then maybe a photo of some of the other animals.

> D6: I would like to see, see the chaffinch, the bird. It's mentioned in the sign, but I cannot see it.

This process of looking for the animals that are described as being present in the visual scene of the diorama can be seen as the visitor's attempt to render the experience minimally meaningful. Interestingly, some of the visitors indicate that this imagined task is initiated after a first search for a more global or higher-level meaning that fails. As human spectators to a visual scene, we will attempt to construct an overall meaning of the visual scene as a starting point before a closer examination of details, but this will often fail, because it is not supported directly by the scene itself or by the additional information provided by exhibit labels. Reading the label for the diorama

will however initiate the task of locating the animals and identifying them according to the label:

> D1: I might miss some of the background for this, I mean, why did they end up living here, why did they die, and how similar are they to the animals today? I think I have a lot of questions that I don't get answered in this picture.

> D2: Let me just see if there's more I need to see [reads sign]. Oh, there's a little bird, I didn't see that. Hi bird!

The diorama: higher levels of meaning

The information not provided by the diorama and its labels can include factual information about the objects of the diorama (e.g. animals, plants, habitat) that could be relevant to visitors relative to their prior background knowledge and interests, but it might also be related to the exhibition as a context for the individual exhibit. The information sought is at first on a level of *phrastic meaning*, i.e. something that could be expressed in a set of sentences. The following quotation is an example of a process of reading and reasoning that leads to a successful resolution of this informational quest. The visitor is reflecting on the beech wood forest diorama and tries to extract some basic facts about the overall meaning of the diorama:

> D1: And it says 'the wood' so I suppose it's now, I mean, it's nowadays: these are the animals I would find in the wood today, but since the other part of the exhibition has been old time in Denmark, I am not sure if this is nowadays, or two thousand years ago, or whatever. I guess it's nowadays, but I don't really... Oh yeah! It's nowadays, yeah.

After this initial search for meaning on a more global level and the minimal task of finding and identifying the objects labeled by the exhibit, visitors will however often go back to higher-level meanings that might or might not be inferred from the diorama. This will typically be on a level of *narrative meaning*, i.e. a story that could be told about the visual scene. Even though these stories are not always directly supported by the dioramas, it is clear that they afford the attempt to create them, i.e. visitors will (given a minimal interest in the topic of the diorama) be directed towards asking the types of questions that a story could answer. This question asking might or might not initiate a process of informal learning. The critical question from the point of view of exhibit design, however, is whether there is sufficient external information provided to support such a reflection (or dialogue between visitors), or if the process is hindered due to insufficient (internal) background knowledge of the visitor as described by Zhang and Patel (2006), and as is evidenced here:

> D1: And then I get a lot of questions or stories that could have been told, but aren't part of the picture, I mean how old do they get, what do they eat, who will eat them, eh... bla bla bla. Eh, there are a lot of stories, but untold. […] I don't expect all stories to be unfolded, but there are so many stories that could have been told here.

There is a kind of desire to arrive at a higher-level meaning that can be seen in the frustration expressed by visitors when they fail to construct it. It can also be seen as a shift in the discourse away from the diorama itself and towards the meta-level puzzle of

the intention of the curators and designers behind the exhibit. This meta-reflection on the exhibit is probably not intended by exhibit designers, but initiated by the failure to accomplish the imagined task or the failure to fully realise the higher-level meaning desired. An example from the beech wood forest diorama:

> D1: And then there's a funny thing about the snail, what's it called, the black slug. I mean so, there are the animals and there's this black slug, and why did they decide to show that? I mean, it could have been ants on the ground, or small snails, or mosquitoes, or... So it makes... gives me the impression that someone has decided what to put in here; it's not everything that should be in the picture. The deer, and then there's this small fellow here. Eh, I don't know if it's because a bird eats it, or someone eats it. Can I know? (Reads) No. So, I guess there's a logic, but I can't figure out why it's there.

The diorama: other issues of meaning

There is some evidence of *episodic and associative thinking* arising from the diorama exhibits. By this we mean expressed thoughts that are not mainly inferential thoughts constructing knowledge of the portrayed scene and its objects, but rather personal recollections triggered by some details. These episodic memories and associations are of course an important part of the personal experience of the museum visit, but they will not necessarily contribute to the educational potential of the exhibit – although in some cases they could:

> D3: Then I take a closer look at the two animals, and I find it like a teddy bear. What's the name of that in Danish... the lynx. [It looks] kind of like a teddy bear. The other one, mmm, makes me think about a book I am reading, about people hunting in the forest.

> D3: (Reading label) I see there's a black slug. I have to find that one! And it's there [...]. It makes me think about the snail... kind of invasion[1], we have in Denmark, where the snails are eating all our plants, somewhere.

Another issue is the secondary *rhetorical meanings* that arise from the interpretation of the diorama exhibits as well as examples of meta-reflection on the diorama exhibits such as the realism issue:

> D1: I think it's realistic without being realistic, because I guess [the animals] wouldn't be that close in nature.

> D1: Eh, for me it's like a painting; it's very idyllic, with green forest and... yeah, it's nearly like a painting. So, the deer with its small child, and so on. So it gives me a romantic impression of life here.

The diorama: multimedia issues

Some dioramas have supplementary media such as ambient sound linked to the exhibit, but these attempts to use multimedia do not seem to contribute to the affordances picked up by visitors – at least in this survey. The ambient sound tends to blend in with background noise from visitors and other dioramas, and sounds can be difficult to identify as arising from particular objects and events:

D1: And I don't know about the noises, if it makes it realistic or just disturbing, because you also have the other [visitors] going around the museum, and then there are these sounds that I don't know. I think it's difficult for me, I mean, to hear the wild boar when it's stepping around. I didn't catch that. So, this should be a mistle thrush. I can mostly hear the water instead of the animals. Yeah, and the noise here, I'm a little bit unsure whether it's from the other scenario, or this is the wild deer, what's it called, wild boar, stepping right now. It must be this one.

Ambient sound could, however, contribute to the imagined realism of the visual scenes by supporting the suspension of disbelief required for the visitor's immersion in the represented scene (Mortensen 2010a).

The discovery room: basic levels of meaning and interaction

As was the case with the dioramas, at a basic level the relation between the visitor and the specimens in the discovery room affords the action of looking. Additionally, the discovery room affords the action of touching and manipulating the objects:

R1: I'm thinking 'deer'! It's interesting compared to the other one [the wild boar], because it has a completely different coat when you touch it. Even though they are both furred animals.

R5: It's a roe deer - a stuffed roe deer. I get the urge to turn it a little bit, because I'd like to see its face… or its head (turns specimen). That's what appeals to me… it's what one wants to see: the head of the animal.

Compared to the diorama one might expect the discovery room to pose a bigger challenge for meaning construction, because there seems to be less information available for the construction, i.e. no information displays, and the objects are presented 'out of context'. However, we find the same mechanisms of distributed cognition at work among visitors in the discovery room as in the diorama exhibit: visitors will imagine a task that makes the object presentation minimally meaningful. In addition to affording visitors to touch and manipulate objects, the discovery room also creates a sense of authenticity:

R1 (about wild boar): It's interesting because it is an animal of that size. I think it becomes more interesting for many people when it isn't just some microscopic thing, but something tangible, kind of like a cat or a dog … So it's good that one can touch them and get a feeling for their structure, fur and things like that.

R5 (about roe deer): It looks as if it is in motion; that it's just about to move. It almost looks alive. It makes me think of a living roe deer.

The discovery room clearly affords an active examination of the objects, but it also affords dialogue. In the case of parents visiting with children the non-familiarity of the object (e.g. a wild boar) is stated as a good point of departure for a dialogue with the child:

R1: Especially if you're here with children you can talk about it because it's something that you don't normally see.

There is also some evidence that the discovery room to a larger extent affords attention to details. This is probably a direct effect of the opportunity to feel and manipulate the

objects, but also the physical closeness with the objects (sensing the size of objects compared to the human body):

> R1: It's interesting how one can sense them – what kind of animal it is, and what size it is, compared to oneself and the other animals. [It's interesting] that you can get close to them here. […] It's great that one can compare the animals to each other. Isn't that a sewer rat? It's great - you can prick your finger on a hedgehog!

> R3 (about the roe deer): I am surprised about the size. There's not a lot of meat on one of those. It's not like the ones you see in The Deer Park[2]; those are quite a bit bigger.

> R6 (about the wild boar): It's… I am so surprised at the size! It's really… well, I know how big a pig is: very big. A sow or boar, galloping towards you - it's huge! I don't know why I had thought they weren't.

The imagined task of the visitor can however be felt as overwhelming. Given the minimal background knowledge about the presented animals, the visitor might be lacking an easy access to supplementary information (other than asking museum staff):

> R1: On the face of it, there is no… I mean, it's a 'touch-the-animals' area, but there could be some kind of text or other interpretation here. Maybe there is, somewhere in the museum. The interpretation is lacking a little bit; when one's memory doesn't suffice, it could have been fun to be able to say more about the animals.

There is an implicit link of meaning and interaction between the animals presented in the discovery room and the animals on displays in other parts of the museum (e.g. the dioramas). Some visitors attempt to utilise this link by trying to remember what was presented in a corresponding diorama, but this is difficult because the discovery room and the diorama space are physically separated.

The discovery room: higher levels of meaning

Compared to the diorama one might again expect the discovery room to pose a bigger problem for meaning construction but this does not seem to be the case. Visitors in the investigation were eagerly trying to infer relevant knowledge through *phrastic* level meanings, i.e. propositions inferred from observing, touching and manipulating the objects, and they also engaged in narrative construction of the same type you would expect from the 'frozen events' of a diorama. Interacting with the wild boar, one visitor produced a series of inferences as well as narrative fictions. Starting from the immediate impression:

> R2: Wow, it's really impressive. It looks really formidable as it stands there. Big teeth and sharp hooves – you'd think it was a predator. A wild boar – but they don't exist in Denmark, do they? Maybe they do. It would be really scary to meet a pig like that in the forest. It looks like it would consider attacking.

From first impressions and the narrative level fiction ('It looks like it would consider attacking'), the closeness and touching affords attention to details and inferences:

> R2: Well, the coat isn't exactly soft, but it's really shiny. It looks like it would have no problem taking care of itself in nature. Don't domestic pigs need sunscreen or something in

order to be outside? They really can't take care of themselves, but there's no doubt that this one can. This is a real pig.

R2: And the teeth – they must be the real teeth. They look quite fierce. It probably has a very hard bite. It is probably much more dangerous than a domestic pig.

As in the case of dioramas there is also evidence of episodic and associative thinking but not more extensively than with the dioramas. Some visitors seem genuinely engaged in figuring out facts about the animals selected from the collection, whereas others mainly focus on their immediate impression. To all visitors the closeness to the animals is important as it affords a sense of authenticity in appreciating the size and feel of the animals as well as their imagined properties (e.g. the 'fierceness' of the wild boar, the 'sadness' of the roe deer).

Discussion

Although the data presented in this paper are used to illustrate the notions of affordance and distributed cognition rather than as an experimental framework to generate new theory, some comments on the employed data collection method are in order. First of all, the choice of the think aloud method was an attempt to gain access to the mental aspects of visitors' interactions with an exhibit, rather than the processed, rationalised version of them available from *post hoc* questionnaires or interviews (cf. Savard, Savard, and Dufresne-Tassé 1994; Mortensen 2011). In our data collection, we thus assumed a simple and direct process of translation from thought to speech. This assumption was based on several factors: we did not observe the lapses into silence interpreted by Makri, Blandford, and Cox (2011) to be a shift of focus to cognitively demanding internal tasks, which could have resulted in altered performance (Fox, Ericsson, and Best 2011). We followed the 'no intervention rule' (Ericsson and Simon 1993), which helps ensure that, engaging in thinking aloud does not affect the performance of the subjects. Our assumption of a simple verbalisation process was further supported by the nature of the verbalisations of the visitors, which in all cases seemed to be of Level 1 or 2 (reproduction of information in the form in which it was heeded, or verbalisation of thought by adding a label or referent prior to verbalising; cf. Fox, Ericsson, and Best 2011), and thus reflected an intact sequence of observed information (Ericsson and Simon 1993). We therefore cautiously conclude that visitors' verbalisations reflected their thought processes during their interactions with the exhibits in the present study.

With this caution in mind, we return now to our original questions: How does an exhibit attract and hold a visitor's attention without the intervention of a human mediator? How does a visitor, who has never seen a particular exhibit before, know what to do with it? And how does the visitor make sense of that interaction?

First of all, the notion of affordance explains how an exhibit attracts and holds a visitor's attention by having physical, geometric or symbolic features that, when conjoined with the visitors' internal make-up, offer opportunities for certain types of interactions and constrain others. Our data illustrated how dioramas offered visitors the basic-level activities of looking for, finding and correctly identifying animals, while the glass fronts of the dioramas constrained touching. Conversely, the discovery room afforded the basic activities of looking at, touching and naming the animals, but constrained the definite identification of the animals because the discovery room objects

did not have labels. In summary, a visitor who has never seen an exhibit before cannot *a priori know* how to interact with it. However, they *can* perceive its affordances and interact with it based on that perception. In the present case, we saw how objects in dioramas and discovery rooms suggested different types of activities to visitors because they were displayed in different physical, geometric or symbolic settings. In this perspective, a central problem of exhibit design becomes an understanding of how the properties of exhibits and exhibitions fit the physical and cognitive characteristics of the intended audience.

When visitors make meaning of their interactions with exhibits, it is exactly within the space created by this conjunction of environmental structures and visitor characteristics that the meaning making can take place. The visitor and the exhibit form a distributed cognition system, where knowledge, practice and meaning making are extended over external (the exhibit's design) and internal (the visitor's internal make-up) representations (Figure 6; Rowe 2002; Jakobsson and Davidsson 2012). Accordingly, it is not surprising that visitors to the dioramas constructed different narratives about the roe deer and the wild boar than did visitors to the discovery room, because the exhibit structures surrounding the objects and encountered by the visitors in these two cases were quite distinct from one another. For example, the diorama exhibit form originated in the early twentieth century to reflect the establishment of ecology as a field of scientific study; its purpose was to allow museum visitors to grasp the interplay between the communities of organisms, geography and geology of a given environment (Fortin-Debart 2003; Marandino, Achiam, and Oliveira, forthcoming). Indeed, in the present case, we saw how the structure of the dioramas steered visitors towards the construction of a narrative about the ecology of the scene they were witnessing. The fact that most of the visitors struggled to create what to them was a scientifically appropriate explanation, rather than generating a more personalised narrative is evidence that the dioramas indeed do constrain ways of interpreting their content towards a more scientific perspective of ecology (cf. Ash 2004; Piqueras, Wickman, and Hamza 2012). However, when visitors were unable to find sufficient external support to construct this ecological narrative, new cognitive actions emerged, such as reflecting on the intentions behind the diorama and on its 'untold stories' (Figure 6). In contrast, the discovery room appeared in the late twentieth century as a way for the visitor to pose their own questions, make observations and draw their own conclusions (Arth and Claremon 1977, Wood 1987). Indeed, this was very much the way visitors in the present study interacted with the taxidermied animals in the discovery room and made sense of them: they identified the animals according to their own knowledge, and in the absence of strong external constraints about how to interpret the animals, the visitors constructed various personalised narratives in which the objects played more subjective roles (Figure 6). We thus find some support for the claim that the medium *becomes* the message (Pedretti 2012). In other words, museum exhibits reflect the educational commitments and intentions of the organisations and groups they represent (Marandino, Achiam, and Oliveira, forthcoming), and these intentions are explicitly or implicitly embodied in the affordances and constraints of those exhibits (Rowe and Bachman 2012). In fact, the visitors probably perceived this meta-relationship as well, as evidenced by the attempts of some of them to reverse-engineer the intention of the organisation behind the exhibits by analysing why the exhibits had gotten to be the way they were (cf. Rowe and Bachman 2012).

The relative homogeneity of the visitors' responses to the dioramas and discovery room, respectively, leads us to suggest that the notion of *genre*, understood as an exhibit

Diorama – constraint perspective

External space

| Display of a natural environment with typical species |
| Occlusion of some animals in the scene |
| Limited description of ecology and life-world |

Internal space

| Limited experience with animals in their environment |
| Some animals are not seen at once |
| Limited knowledge about the ecology and life-world |

| Recognise familiar animals |
| Search for and locate "hidden" animals |
| Limited knowledge about the ecology and life-world |

Resulting cognitive affordance space

Diorama – action perspective

External space

| Observable diorama & taxidermied animals, etc. |
| Display of a situation or "frozen" event |
| Labelling of species on signs |

Internal space

| Observe naturalistic scene & recognise familiar species |
| Recognition of situations and events |
| Reading species information |
| Interpret the meaning of the scene as a whole |

| Observe naturalistic scene & recognise familiar species |
| Recognition of situations and events |
| Locate animals and identify species |

Resulting cognitive affordance space

| Inquiry about ecology of the species, "untold stories" |
| Meta-reflection on design intentions |

Discovery room – constraint perspective

External space

| Collection of skeletons and taxidermied animals |
| Animals out of context |
| No labelling of artefacts |

Internal space

| Limited recognition of specimens |
| Limited experience with animals in their environment |
| Limited sense of task for the visitor (design intention) |

| Limited recognition of specimens |
| Limited experience with animals in their environment |
| Limited identification of species |
| Limited sense of task for the visitor (design intention) |

Resulting cognitive affordance space

Discovery room – action perspective

External space

| Direct access to collection |
| Touchable and moveable animals and skeletons |
| Spatial proximity |

Internal space

| Selective exploration and visual observation |
| Touch, feel, lift, move animals and skeletons |
| Use own body as size gauge |
| Personal narratives |

| Selective exploration and visual observation |
| Tactile & kinaesthetic experience of animals |
| Realisation of actual scale of animals |

Resulting cognitive affordance space

| Imagined actions and habitats of animals |
| Personal narratives |
| Experience of authenticity |

Figure 6. In the *constraint perspective* the external and internal constraints are added in *the resulting affordances space*, whereas in the *action perspective* the possible actions are only those actions that are supported externally as well as internally.

classification scheme based on style or form, could meaningfully be used to distinguish exhibit types from one another. There is evidence to suggest that the chosen exhibit genre constrains how science can be transformed into exhibit content (Mortensen 2010b); the present study suggests that exhibit genre also constrains the way exhibit content is acquired by visitors. Understanding the specifics of an exhibit genre, i.e. its genre-specific affordances and constraints, could help designers create more efficacious exhibits because it would enable them to better take advantage of the distinct ways of mediation of the genre in question.

On the other hand, the notion of exhibit genre and genre-specific affordances should be used with some thoughtfulness. The assumption that certain types of exhibits have certain universal affordances presupposes that all visitors share certain perceptual and conceptual schemata (cf. Allen 2004). While this may be the case with regards to more basic-level opportunities for action (e.g. buttons for pressing or levers for pulling), it may not always be so for higher-level, cognitive opportunities for action. And although discontinuities between how an exhibit is planned and how it is experienced can be conducive to visitors' meaning making (Beghetto 2014), the disadvantage of a too-wide gap between intention and experience could be the exclusion of the visitor. Indeed, it has been shown that exhibition design, through the use of culturally specific codes, can have the effect of excluding visitors from participating because those visitors belong to different cultures and thus are unable to decipher the codes (Dawson in press). We would therefore caution against an uncritical application of the notion of genre-specific exhibit affordances, and encourage exhibit designers and researchers alike to continue to explore and develop the scope and variability of the various exhibit genres to ensure the inclusion of a diversity of visitors.

Acknowledgements

Notes

1. The 'snail invasion' is a reference to the recent invasion in Northern Europe by the Spanish slug (*Arion vulgaris*), which is considered a serious horticultural pest.
2. The Deer Park (*Dyrehaven*) is a well-known forest park located north of Copenhagen, noted for its large populations of red deer (*Cervus elaphus*) and fallow deer (*Dama dama*). Both species are considerably larger than the roe deer.

Notes on contributors

Marianne Achiam (née Mortensen) is an Assistant Professor at the Department of Science Education, University of Copenhagen. She has an M.Sc. in Biology and a Ph.D. in Museum Didactics. Her research interests include science and particularly biology dissemination in informal contexts such as museums, science centres, zoos, aquaria and botanical gardens. She is the coordinator of the Departmental research group on science education in informal settings.

Michael May is an Associate Professor at the Department of Science Education, University of Copenhagen. He has a Ph.D. in Psychology and B.Sc. in Cultural Sociology. His research interests include science education, e-learning, philosophical and didactic aspects of modeling in science and semiotic aspects of formal and informal learning.

Martha Marandino is an Associate Professor in the Faculty of Education at the University of São Paulo/FEUSP, Brazil. She graduated in Biology and has an M.Sc. and Ph.D. in Education. Her research focuses on science museum education, science education and science communication. She is the coordinator of the Study and Research Group on Non Formal Education and Science Communication/GEENF/FEUSP (www.geenf.fe.usp.br).

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