Ambient Adaptive Lighting

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Abstract

The concept of adaptive lighting suggests architectural lighting designs that adjust and react to the living practices of inhabitants and variations in the environmental conditions. Current developments in lighting technologies, such as LED light sources and IoT infrastructures, open for new opportunities with adaptive lighting, where the control of the lighting possibly operates as an IoT service rather than build into building management systems.

The dynamic flux in lighting changes the experiential presence and brings focus on change and variation rather than states, levels and structures. The suggestion is to enable adaptive intertwinement through an expanded field of dynamic flux in the artificial lighting, and couple between the daylighting and the artificial lighting through an integration of ambient contexts.

The project develops experiential prototypes, with which the dynamic design parameters of adaptive lighting can be investigated, analysed and scoped into architectural programming processes. The staging's are full-scale architectural scenography's, which situate investigations into how the experience parameters of fluctuating artificial lighting, integrated with daylight flux in an architectural space, are experienced to influence the experience of architectural space, social situations and everyday activities.

Keywords: Light, daylight, adaptive lighting, ambient, dynamic light

Adaptive Technologies

The new lighting technologies, such as LED light sources and infrastructures of connectivity and data communication, develop expanded opportunities for complex coordination and control. This enhanced infrastructure allows for the development of relational design paradigms, such as adaptive lighting.

"adaptive lighting dynamics has potentials; they enable a new condition"

The emerging adaptive control paradigm utilises Internet-of-Services to coordinate abstract information and scenarios across previously separate domains of building technology, living practices of inhabitants and architectural lighting design.

The new light sources, such as LED, are adjustable and individually controllable, which enhances the time-based aspect of lighting design and opens for new detailed qualities of lighting dynamics. Simultaneously the development of smart building adaptivity based on IoT infrastructures will enable coordination between lighting systems, sensor networks and the living practices of the inhabitants.

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Design opportunities emerge with dynamic and adjustable lighting, opens for the dynamics of adaptive lighting to be included in overall architectural design considerations in a much more elaborate way. Adaptive designs can include how lighting systems continuously adjust to environmental lighting conditions, for instance daylight flux. It can involve adaption to shifting user scenarios, individual needs and consideration of health and wellbeing. It can include decisions of energy usage and demands related to the indoor climate.

Figure 1. The experiential prototype in the lab.

The developments towards lighting adjusted to human experience, and the luminous environments adjusted to sensibilities of architectural design, follow the ideas of W.M.C. Lam in his seminal work: ‘Perception and Lighting as Formgivers for Architecture’ (Lam 1977) and the design strategies explicated in D. Kuntzsch edited work ‘Light Perspectives: between culture and technology’ (Kuntzsch 2009). Perspectives on lighting design that seek to emphasise the experiential and formgiving qualities of the luminous environments, but with the adaptive lighting dynamics brought into concrete relation with the flux of daylight and the fluency of perceptual adaption.

New spectrum distribution in artificial light

The LED technology generate light in very narrow bandwidths, which is then brought into emitting a broader spectrum of light through phosphorus coatings. Current developments seem to enable an even spectrum distribution across the colour scale, and even beyond current limits toward a spectrum similar to the visible part of daylight. This correlation of colour distribution similar to natural light spectrum enables a more fluent integration between natural and artificial light and opens for enhanced design opportunities of the composite illumination of architectural space. Furthermore, the composite LED engines, such as tuneable white, allows for a separation between the variations of luminous levels and colour tone, and thereby enables fluid changes of colour and intensity across scales by choice in the moment.

New presence of luminous bodies with artificial light

With the ability to distribute and embed LED in to any shape and surface, the presence of the luminous source changes towards luminous material, forms and zones, as well as emitting very clear and directed light as points, lines and luminaires. The light can be embedded in walls and texture where the luminance comes from the material or arrive from non-distinct primary source, and thus form part of the lighting design in ways previously normally enabled by reflective surfaces and object. [i]

Figure 2. The experiential prototype in the lab.

New dynamic presence of artificial light

The technical construction of LEDs opens for detailed and instant control of the qualities of the emitted light. The connectivity and feedback opportunities of networked lighting infrastructures allows for fluent variations in the composition and dynamics of the lighting bodies and how the lighting shapes presence of space. The control infrastructure allocates the possibility for advanced software to form the composite dynamics of the light and facilitate fluent dynamics across spatial distribution and durational development. This inherent dynamic presence of the luminous environment produces a design condition, where continuous variation could be viewed as the norm, and stable light as an exception.

IoT and building automation

The infrastructures needed for the development of adaptive lighting automation is emerging from industry-research collaborations, such the standardisation project OpenAIS[ii], an EU supported initiative, which have developed specifications for an IoT based, Lighting-as-a-Service infrastructure[iii]. The technical specifications in the OpenAIS project will influence a common EU standard towards 2020 [iv]. OpenAIS allows for integration of an open-source Internet-of-Things system architecture with networked and interconnected devises. The IoT infrastructure opens for the new building management and design model: Lighting-as-a-Service. Management as well as design becomes services, attributed to the infrastructure rather than build-in. The infrastructure connects to everything else in the building (heating, sun shading, security, etc.)[v]. The services potentially allow for continuous adjustment of the building design and support changing usage patterns and enable customised services to each individual user.

Functions, management and services are customised, selected individually by users, gradually transformed and adapted to changing needs and desires. The building behaviour becomes adaptive and in continues transformation. This type of automation is, as suggested above, very different from previous control paradigms with centralised and pre-configured control. It is a transition towards software-based management, as a service, in a systematised network of devises. The adjustment to new lighting technologies, altering user scenarios, input from sensor elements and data streams is happening through software updates rather than physical reconfiguration. The maintenance of functions is an evolutionary process of gradual and frequent updates. The architectural lighting design enables capacities of potential operations rather than pre-defined function. These developments of the adaptive lighting design are concrete realisations of what in other scales are described as Smart Homes, Smart Buildings and Smart Cities[vi].

Services for flexible solutions

The lighting infrastructure is the last to be negotiated as a platform within the IoT paradigm due to the complexity of designs and functions that lighting is involved in beyond mere illumination. The central and entangled role of lighting and its infrastructure will further expand in the future. System of the future will be the communication backbone, through wired network, wireless network, light as network, and the infrastructure will provide two-way data streams and therefore effectively making a mesh of interrelated nodes across every square

meter of space, with capacities to engage with any element attached to the system, wired or wireless, e.g. thermostat, blinds, sensors etc.
A particular feature in the way these new infrastructures are thought and designed is that they do not exclude non-connected elements. There is connectivity through feedback between the luminous and the data world through sensors, and there is feedback between system through data flows. The ordinary lamp with independent switch is part of the system through light sensors. The ordinary central control unit in the building management system is incorporated as part of setting the scope for the software driven automation. There is as such an opportunity for enabling robust redundancy into all levels of the system architecture, minimising dependence on the complexities of such systems. The layered, abstracted and software driven processes enable integration of localised manual systems and is in no conflict with the single person turning on their individual non-connected luminaire.

You can have radical different services from your neighbour, and building can be re-configured and re-designed in gradual ever ongoing transition. Enabling variations related to personal desires, weather and daylight variations, adjustments to daily rhythms, responses to flux in the energy supply, or political decisions on usage patterns, are provided by the services. Unfortunately, this type of flexibility only become available when the infrastructure passes the threshold into a full-functional software service platform, where functions are applied by software after the place is personalised and maintained by software providers dislocated from the user. Simple functions and relations can be implemented, but the more radical transition is dependent on the adaption of common standards and the implementation of smart devises.

Ambient computing

The new IoT infrastructure platform generates a condition of ambient computing as a consequence of the ubiquitiveness of the computational capacity in the fabric of the building material and functions. None of the elements (devises, functions, materials, forms) exists by themselves but act as mediated correlations, which seen from a user perspective allows for simplicity on a higher level of abstraction in the experience of the automated activities (a response to sudden daylight influx might enact correlated activities across shading, transparency, reflection and lighting in negotiated scenario dynamics). The distributed and embedded computing allow for composite responses made up of many dynamic constituents. These responses can be generated specifically to what is relevant in the moment, as procedural content generated out of pre-defined parametric relations.

The experiential prototype staging has embedded a generative software environment, named ‘Digital Weather’ in this project, which is our first implementation of such a parametrised generative software.

The system environment envisioned are different from management system with pre-defined response scenarios in the way they become continuously adjustable without prior prescripted options. This is achieved by the connectivity of all elements into an abstract software environment, where the behaviour of the ecology of elements can be generated separately from the physical function of each element. The suggested design explorations with experiential prototypes aim to enable investigations into this new adjustable field of design. What could be the relevant model for the design, and how is that qualified through experience into design strategies?

Perception of Dynamic Flux

Fluctuous environments

The new light sources are adjustable and individually controllable, which enhances the time-based aspect of lighting design and opens for new detailed qualities of lighting dynamics. The time-based aspect of adaptive lighting opens for dynamics relative to other elements such as daylighting flux and the fluidity of everyday living practices. We have asked: How will the inhabitants experience these adaptive conditions, and how might lighting design strategies support comprehensible designs? How are the flux and transitions to be understood, designed and be incorporated in everyday living practices? How do we enable proper sketching environment for architectural lighting designers on the design qualities and strategic parameters of the dynamics of adaptive lighting? The suggested research methods and prototypes enables experiential investigations with focus on the fluctuating dynamics of the luminous environment, and through the participatory engagement in experiencing while adjusting, we are able to incorporate the adaptive dynamics of visual perception relative to the dynamics of the lighting fluctuations. (Figure 3).

Figure 3. Three states of the adaptive lighting in a situation with two participants. This is staged for the camera and therefore the changes are made very explicit. In the ambient settings of adaptive lighting only nuances appear.

Perception in Action

The experience of lighting in dynamic flux re-directs the attention towards how the lighting is experienced by inhabitants in their flow of living practices rather than how it can be analysed from formalised and generalised overview as light in 3D space. In the flow of living the experiential situations change, the inhabitants move around, and the eyes change focus and direction continuously. Seen from the perspective of the inhabitant, the experiential condition could purposefully be viewed as perceptual processes of multimodal actions.

The philosopher Alva Nöe (2006) suggest an enactive approach to perception, and the core concept ‘perception in action’ as a perspective towards this experiential condition. We are, he observes, sensing, probing, rehearsing, and adapting to the experiences in a continuous perceptual negotiation. Sensing, experiencing and perceiving is in the enactive view not a sequence of course and effects, but entangled in ways that integrate the processes: the activities involved in perception are mutually dependent and dynamically adapting in the flow of enacting our living. Our vision capacities do not, as perception processes, resample a camera or camera obscure, but is an enacted performance of probing and correlating between impressions, previous experiences, and the narration of our lifeworld. Light and colours are features of the environment that appear through the perceptual activities. The view is here that experiencing, and the perception in action, is intentional activities, enabling perception as ‘a *way of* thinking about the world’ (Nöe 2006, 189), and that ‘Insofar as perceptual experience is intentional, experience seems to be bound up with our broader capacities to *think about* and *understand* the world.’ (ibid, 189). The experience of the lighting environments is then real and meaningful instantly, but with possibilities for changing assumption through perceptive activities.

The enactive view on perception is a position that seems to be able to facilitate a view on adaptive lighting as a dynamic flow of continuous emergence of enacted experiences, rather than the dynamics becoming a disturbance of assumed stable conditions. The assumption is that we have to learn to experience what we experience, and we have particular processes and strategies, biologically and cognitively, on which we rely to be able to see and understand space and our place in space. We have the pre-conditions, but need to develop and refine sensory modalities, that are adequate for the experiential task at hand. The enactive approach aligns the experiential qualities of adaptive lighting with those experiences evolving in encounters with the flux of daylighting, and thus enable a lighting design paradigm that integrate and reach across natural and artificial lighting.

Rehearsing sensibilities towards adaptive lighting dynamics

Alva Nöe (2006) explicates the experiential perspective as a relational process between actions of perception: the world appears because we engage and deliberately enact perceptive account of ourselves in the world and the word surrounding us. The focus is not on how we perceive, but on how we make perception appear: "… perceiving is a way of acting. Perception is not something that happens to us. It is something we do (Nöe 2006, 1)". The knowledge of the spatial composite appears through reflections on our movement: "Size, shape, voluminousnes, and distance are experienced by us thanks our possession of sensorimotor knowledge (ibid, 79)" and "perception may be a mode of encountering how things are by encountering how they appear (ibid, 85)". Nöe formulates the enactment of perception as a continuous learning process and gradual adaption to how we experience, which have the consequence that "perceptual adaption, from the enactive standpoint, is a process of learning to apply the appropriate sensorimotor knowledge. Once this is accomplished, content is refashioned (ibid, 92)" by processes where "…one's sense of movement (kinesthesis) and body position (proprioception) come to adapt to vision (ibid, 93)".

The enactive approach to adaptivity builds broadly on an ecological approach to perception, as envisioned by J.J. Gibson (1979) in 'The Ecological Approach to Visual Perception' (referenced by Nöe 2004, 20-21). The idea that sensing and acting, by ourselves and in relation to others and the environment, can be viewed as an interrelated ecology of events, mutually constitutive and interdependent, all forming part of our experience of our lifeworld. The evolutionary attunement between animal perception and living environment, as embodies wholes, correlate sensing and acting as a dynamic flow, where objects, persons, surfaces and architectures, as well as the more composite complexes of lighting, visibility and appearance, is emerging in the active process of living through integrated and composite experiential processes. These observations become especially relevant when the lighting environment are in constant dynamic flux, and cannot be counted on as a stable factor in the perception activities. The stable factor is then the radical first-person view of being in activity.

Staging experiential investigations

The enactive view highlights the constant probing activities of visual perception, moving eyes and head, as well as the body position, distance, speed in space, often in repeated investigatory patterns, to constantly re-assess the perceptual processes. The prototype environments and staged investigations, outlined in this paper, enable an expert situation for deep rehearsal and investigation into the correlations between adaptive dynamics and active living practices. Our imperfect access to the world, as a process of experiential coordination of multiple sensory and cognitive modalities, is brought into play in the experiential design investigations. (Figure 1, 2 & 3).

In an attempt to grasp the dynamics of experiencing, the semiotician Per Aage Brandt (2002) introduces the term 'the human real', – an endeavour to develop a cognitive semiosis as a non-reductive, semiotic realism. Brandt suggests that the appearance and cognition of forms in the environment is emerging within the cognitive processes as a meaning building process, a process of semiosis. Our cognitive capacities act with a time-window of approximately 3 second for the experience of now (experience of actions and dynamics), and 7-10 seconds for the appearance form (recognition of form and space), which then are the constituents of the duration of experiential form. We are, in this view, cognitively primed to encounter environments in flux and find firmness in our experiences through the very active processes of semiosis. What we experience through our living practice is what feeds the experienced reality of the person, and through a continuous weaving of meaning, processes of semiosis, the person develop and maintain adequate understanding of their experiences.

A further weaving of the experiences into an understanding of the environment and one's experience of place within it, might be described as narrativation: the active process of narrating experiences in the flow of their appearance, as articulated by Monika Fludernik (2006). She terms this emergent view on sense-making 'post-dramatic', in the sense that in the process of continuous narrativation, the experiences immediately transform into perceptive context for the next experience. The narrative experience seen as emergence rather than evolving from preconceived narrative structures. The actions generate events understood in the context of situations, which is then transformed by the action and events to new contextual situation. These enacted perceptual processes, the semiosis of the apparent as real, and the continuous adaption of narrative context, are the core components in the staging of explorative narratives in the prototype environment.

The staged prototypes enable an integrated analysis through design probing, using staging methods similar to and influenced by experiential staging strategies deriving from the scored actions in Fluxus events (Hendricks 2008), Happenings (Kaprow 1993, Sandford 1995) and performance art (Petersen 2011c). Scores of activities organise patterns of actions, events and situations, and thereby form the experiential investigations as they evolve over time and through space as a continuous process. The interest is in the morphology of the dynamics; how the experiential process couples with the flux of light; and how to stage an analytic and creative processes with distinct validity for the lighting design. Staged as experiential processes that aim at rehearsing and maturing the ability to analyse, reflect, sketch and design adaptive architectural lighting.

Figure 4. The flux of daylight as experienced within 30 minutes in June 2017 in Denmark.

Dynamics of Ambience

Adaptive intertwinement through dynamics of ambience

The concept of adaptive lighting suggests architectural lighting designs that adjust and react to the living practices of inhabitants and variations in the environmental conditions. The dynamic flux in lighting changes the experiential presence and brings focus on change and variation rather than states, levels and structures (Petersen B2015b). This change from static to dynamic alters of core aspects of lighting as design material. The suggestion is to enable adaptive intertwinement through an expanded field of dynamic flux in the artificial lighting, and couple between the daylighting and the artificial lighting through an integration of ambient contexts. (Figure 4). Ambience in this thinking is the experience of fluctuations integrated as context, as an emergent material quality in-between several environmental influences (Schmidt 2010, Böhme 2013). The suggestion is that adaption through the contextual qualities of ambience will expand and qualify a much larger range and dynamics in the lighting, and thus expand the qualitative design scope for adaptive lighting (Maglielse 2009).

The philosopher Ulrik Schmidt (2013) builds upon the aesthetic problem related to the more fluid states of the forms of light and space, experiential problems which are particular prominent in adaptive lighting. He discusses the special qualities of ambient space, referring to Böhme (2013). Here he suggests that ambient space appears as intensities rather than as contours, shapes, scales, and perspectives. One can say that with the dematerialising variance of adaptive dynamics “intensity is added as the spatially defining parameter” (Schmidt 2013, 19) and the “gradual and graduated modulations in space unfold in different ways in a condensed passage in a concrete sense [...] which the subject can follow intentionally, or physically enter into, without ever leaving the environment at any time. Formations and modulations concretely take part in the environment as continuous, intensive variations” (ibid, 19). Through the adaptive dynamics there arises a new firmness in the experience of spatial shape through relationships arising in intensities in an otherwise dynamically changing context – a relationship in the experience facilitated by the perceptive constancies[vii], where “the surrounding’s different elements weave [...], in all their diversity, together into a consistent plan” (ibid, 19). Adaptive dynamics thus generate a continual variation in spatial definitions, retracting the firmness of relational space in terms of the categories of scale, form, and perspective – in order to instead introduce ambience, defined by fluid constancies of intensities occurring within changes.

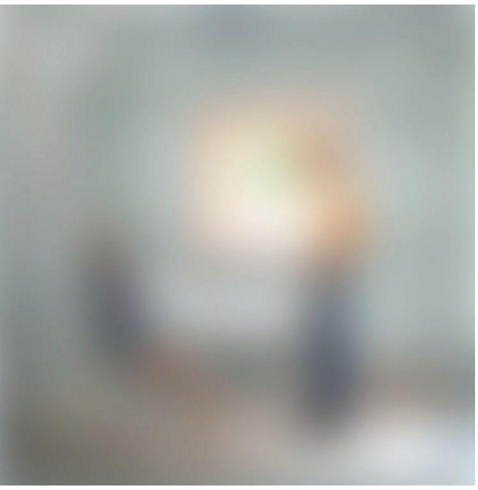

Figure 5. A very crude way of illustrating the ambient surrounding effect could be a blurred image like this; the motif is neither distinct nor indistinct.

Ambience and the adaptive light

The adaptive light functions as an environmental effect, a quality attached to the dynamic light in the environment, most similar to the way the influx of daylight presents itself as complex environmental. As experience, the movement in the light is a combination of the dynamics of the light itself, the dynamic processes of perception, and the experiencer’s vision activities and movement in space. A central concern with adaptive lighting is to maintain the visual experience as ambient, that is, as environmental consistent. If one views architecture, and architectural lighting, as a basically ambient practice, then the design of physical space (Schmidt 2013, 71) can be seen as establishing particular physical framings, which stages the lighting conditions and “promote the environmental character of the framing and the sense of being surrounded” (ibid: 72). The compositional material within adaptive lighting is that ambivalent condition of the lighting phenomena appearing as significance to the ambient form, neither disappearing into diffuseness, nor appearing into particularity, but the dynamic potential in-between: the ambient light. (Figure 5).

Digital Weather Generator

Evolutionary design generation

The ambient mediation in the adaptive lighting is delivered by a software generator, which we call ‘Digital Weather’, conceptualised and designed by the software artist Ole Kristensen[viii]. The design of this generator is based on processes used in games, where environments, scenes and texture are continuously generated as the game unfolds. It is a change from lighting management system with pre-defined scenes and behaviours, to a design of potential variations, which is navigated from a set of generative parameters. Within this generative capacity, formulated in software, there is no limitations in number of dimensions that can be involved. There can easily exists several time-perspectives simultaneously. There can be feedback of sensor input on actual lighting conditions in the space or related to outdoor lighting dynamics. It is an important aspect of the substance of dimensional and integrated software, that it coordinates across modalities and experiential domains, which for the human normally are separate categories, and uses weavings of relational parameters in the creation of lighting dynamics rather than data on measures and states. The design of generative compositional algorithms is in definitions of scope and procedures, which negotiate lighting outcomes that is not defined in the system but emerge from the system processes. This enables a larger scope of outcomes and a clearer negotiation of relevance.

The software driver of the adaptive operations is a system of Procedural Content Generation (PCG) (Shaker 2016) based around the Perlin generator algorithm (Perlin 2017, Bevins 2017), which allows for parametric control of textual phenomena with material qualities reminiscent of natural occurring phenomena. (Figure 6). The assumption is that if we view the fluctuation of light as an experiential material, then the perception of artificial lighting fluctuations can be generated reminiscent of daylighting, and thus allow for more seamless integration of for instance daylight influx and the indoor lighting.

Figure 6. Two instances of Digital Weather produced by Perlin Noise generated images.

The design of a generative system, rather than a configured management system, opens for adaptive lighting dynamics, that have pre-defined scope of options and a complex relational coupling to contexts and environment. Compositional systems within the context of parametric design defines a set of rules where the parameters are selected but the values and dynamics are a result from events outside of the control of the system, either as generated values from generative algorithms, or as contextual data from sensors or other control systems. In the Digital Weather we use a predictable, or at least repeatable, generator using the particular capacity of the Perlin Noise algorithm. This is not a noise in the sense of generating variation of uncontrolled random output, but an algorithm that enables complex orders of outcome beyond immediate prediction. The outcomes can be probed and selected for their experiential qualities, and then used to define the boundaries of the scope of activity of the Digital Weather. The Digital Weather is in a way a particular weather system with well-rehearsed variables and scope of outcomes.

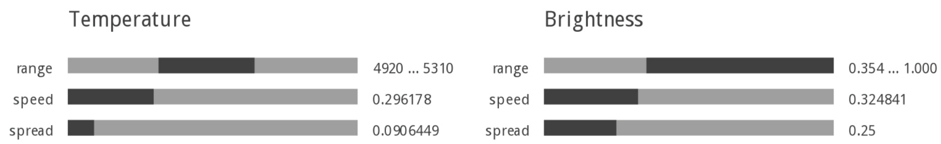

Figure 7. The simplified view of the core parameters, scales and ranges that compose the dynamics of digital weather system.

The Digital Weather is a rule-based system, which inherently has the potential for variation by changing the value on the defined parameters. (Figure 7). Some aspects are not parameterized and will not have variables. These can be constants or boundaries that define the concrete specifics of a design space, for instance the position and type of light sources, and the shape and reflectivity of the architecture. Other conditions can be dynamic but outside the reach of the parametrised system, such as the daylight influx and the turning on or moving of individual luminaires. The variables only make sense within a certain range. Defining the range of values is one way that designers can assert their aesthetic sensibilities in a parameterized system. Finding the parameters for the Digital Weather and defining their probable ranges, scales and speeds was developed through a complex process of design iterations, repeatedly probing and testing different possibilities until a final set of variables was reached. The final version has a limited set of high-level parameters that satisfied the design demands of a delicate and nuanced pattern that also was able to produce a vibrant dynamic outcome.

Experiential Prototypes

Almost all areas in our lifeworld require some form of competence and experience in order to be seen and understood. The radical character of the fluidity and relational capacity of adaptive lighting could be in need of experiential investigation to gain competence on how it appears and influences our experience of light, space and each other. The suggestion is to meet the adaptive lighting dynamics on a compositional level rather than a functional, biological or psychological level. Like music is a combined effort of rehearsing, listening and performing, guided by structures for composition and strategies for rehearsal, the reach towards adaptive lighting and fluid integration of artificial light with the flux of the environmental light flux, reflections and movement, require an enhanced analytic and design capacity. The instruments and methods described in this paper have the role of staging and guiding the rehearsal and development of experiences and capacities for adaptive lighting design.

Staging experiential Prototypes

The concept of 'experiential prototypes' emerges out of arts based methods of minimalist art (Battock 1995), installation art and performance art. The minimalist ideas of shaping experiences by staging simple form, such as the sculptural works of Robert Morris (1993) where the introduction of very simple sculptural elements in space situate complex visitor activities and experiences. Significantly the participatory artworks at the exhibition 'Bodyspacemotionthings' at Tate London 1971 and 2009[ix]. The Olafur Eliasson's exhibition 'The Weather Project' at Tate London 2003-4[x] extends this approach to one elemental effect: a mirror. The visitors are situated under a gigantic mirror image of the space and can perform for themselves, for others and as part of a collective enterprise, all situated by the minimal spatial intervention of the full-ceiling mirror (Ursprung 2016, 118-23).

The activities of installation art have a diverse history across fields of art (Petersen 2015), including the visual staging of painting, theatre, film and games. In the context of experiential prototypes the main perspective is of installation art as environmental instruments that attunes the visitor to particular sensitivities, and structure participatory activities through the staging and scripting of a particular experiential situation (Søndergaard 2010). The adaptive lighting prototypes is an experiential instrument focused on the relation between the flux of light and the fluency of perceptual adaption. The experiential prototypes create reflective environments (Petersen 2011b, 2011c), within which the investigators can perform. Through systematic explorative rehearsals, the investigators perform their engagements while experiencing, analysing and testing aspects of the dynamic design parameters of adaptive lighting. To the extent that perceiving is tied to actions and sense making to semiosis and narrativation, the enactment of adaptive lighting investigations could be viewed as 'lived abstractions', as Massumi envisions (Massumi 2009), articulated into the world of professional dance and performance by Maaike Bleeker (2016, 35-53).

The methods of investigation combine architectural probing and performative engagement. Architectural probing such as sketching spatial dimensions and positioned relative to the larger environment (Burry 2016), and the staging of participatory engagement in installation art, within which the visitors perform their own experience while probing social situations (Petersen 2013). The experiential prototypes could be classified as *speculative*, by the way they enable sketching of ideas on adaptive dynamics and refinement of design parameters within a refined full-scale and perceptually correlated environment. These speculative situations are not designed to verify, measure or quantify any parameter directly applicable to a building. They are designed to enable the development of a scope for architectural programming. The investigations with the experiential prototypes are meant to refine a first set of variables and models on an adaptive lighting paradigm.

Architectural programming for adaptive lighting

Architectural practice has design processes in several stages and situated in different context. The experiential prototypes, and the scope of design options they situate, fits to the early programming process of an architectural idea. Not related to a particular building or building topology, a specific place or inhabitation practice, but programming as the process of scoping the architectural challenge into a comprehensible synthesized model, that can be utilized to guide the further process into a particular implementation.

The suggestion is, that adaptive lighting with its merger of experiential dynamics, architectural form and flux of light from the environment with complex dynamic artificial lighting, will best be understood by actual inhabitation in full-scale prototypes. As Edith Cherry (1998) argues: “the architectural programming is defined as a process of problem analysis and identification” (p.xx), and, ”architectural programming is the research and decision-making process that defines the problem to be solved by design (p.3). The specific of the design scope is only occurring when related to a concrete architectural proposition.

Further studies will need concrete contexts in actual inhabited buildings with real-life activities, to enable the complexity and variance of the real to be the context for a formalised analytic set of events. Attached to these future contextualised studies, the effect and qualities of implementations of adaptive lighting can then be studies, measured and possibly formalised into generalised insights.

Formalised performance of presence in space

How the investigations are performed in relation to the prototype has its roots in performance arts: the activities of developing detailed experiences and capacities to perform by systematic investigations. Sometimes this is called ‘to develop the character’ and ‘to inhabit the space’. In the experiential prototypes for the investigation of adaptive lighting these methods of engagement and rehearsal is formalised as investigative inquiries on relations between a design and the experience of engagement within that design. (Petersen 2011a)

The staged situations in the prototype builds on a few core scenarios of persons inhabiting the set. The scenarios have a few different social configurations in the space, as simplified analytic event of spatial presences, enacted from simple scores that describe the dramaturgy of the acts to perform. This approach is based on simple relational categories: (1) the view of the other person, face or whole body, and their lighting conditions; (2) the sense of one’s own position and lighting condition; and (3) the sense of relation to lighting conditions outside the set (e.g. through the window) and the influx of light from outside. In short: the relation to oneself, to others, and to the environment. From this basic model of relations, scores of performing experience are scripted and repeatedly performed.

The analytic situation is then a collaboration between at least three people, who take the roles of (1) performing/experiencing enactment, (2) observing and documenting the performance, and (3) directing the performance and the adaptive lighting design. Through a schedule of rotation of roles, iteratively creating and rehearsing, the participant gradually develops a capacity of insight from the combined viewpoints. Through the constant processes of performing-observing-directing and the simultaneous processes of adjusting designs, testing experiential qualities and articulating observations, the team refined an insight into design qualities while probing design strategies.

Probing the dynamics of visual experience in adaptive lighting designs

The prototype is built in 18% grey material with slight transparent and rough textual material so that from this neutral basis the light can equally change to more or less luminous, more or less coloured towards warm and cold white, and more or less solid, reflective and luminous. The design enhances focus on the relative changes through the dynamic of the light, rather than on absolute luminous levels, colour tone and presence of materials. This design allows for variation in all directions adjusted to the perceptual capacities of our experience of light. The design enables that the experiential investigations can integrate the flux of perceptual adjustment of the human visual system alongside the flux in the dynamics of the light, enabling tests across the range and variations inherent to visual adaption. In interest in the relative dynamics of perception, action, adaptive lighting and environmental flux, rather than any specific spatial configuration or luminous composite.

The interest of the investigations is primarily in how dynamics in the lighting flux correlate with the experience of the space and presence in the space, and thus the dynamics of perceptual adaption is an integrated element in the probing of the possibilities for fluent dynamics in the artificial lighting. The offset for the investigations and the experiential prototype rest on a three-year artistic exploration into understandings of the adaptive dynamic features as experiential form, and a first attempt to outline a model of dynamic scales and parameters that reach between software behaviour and experiential materiality. An outline of these investigations is published in the books: 'Adaptive Lighting, (Petersen 2015a) and 'An Exploration into Integrating Daylight and Artificial Light via an Observational Instrument' (Petersen 2015b). (Figure 8 and 9)

The design of the instruments – experiential probing environments

The instrument makes certain aspects clear and analytically available – the set-ups are detailed formed towards the particular framings, concepts and parameters under investigation. Other questions would require a different prototype design. The prototypes enable sketching through experiential activities – as abstract and as concrete as drawing or performing. They are adjusted to visual perception with a middle level in light transparency, luminosity and contrast regulation. They have clear marked directions in space and grey/white painted furniture objects. They have soft borders of the space to be able to fluently walk in and out and extend the probing space. There are well-structured visual directions and view lines, and observers of the events can situate themselves and adjust to any particular condition under investigation.

The challenge of adaptive lighting dynamics has potentials, they enable a new condition, and therefore the prototype is an attempt to stage the full estimate of that new condition. What comes into strategic ability is a parallel development of insights into dynamic lighting design, experience of inhabitation, and development of generative software. The prototypes are instruments, not something like architectural mock-ups or in any way aiming at lighting design propositions. They are abstracted staging's of a refined set of variables, to enable investigations into the core parameters of an adaptive lighting design strategy. We have arrived at a set of scales, ranges and relations – a tuned investigation tool-set. The scope for adaptive lighting is very large given these qualities in the variations of the dynamics, but as a starting point, the investigations have focused on the subtle continuous adaptions as ambience in and of the environment.

Figure 8. The 'Adaptive Lighting' project in 2012-15 investigated the particular adaptive relation as experiential accounts, when the lighting follows the activities of the inhabitants. Direct relations between position and movement followed by luminous or colour change, or subtle variations on how the lighting dynamics follow or are followed by the person. Situations investigating the relation between several people when situated in lighting adapting to places or people in space.

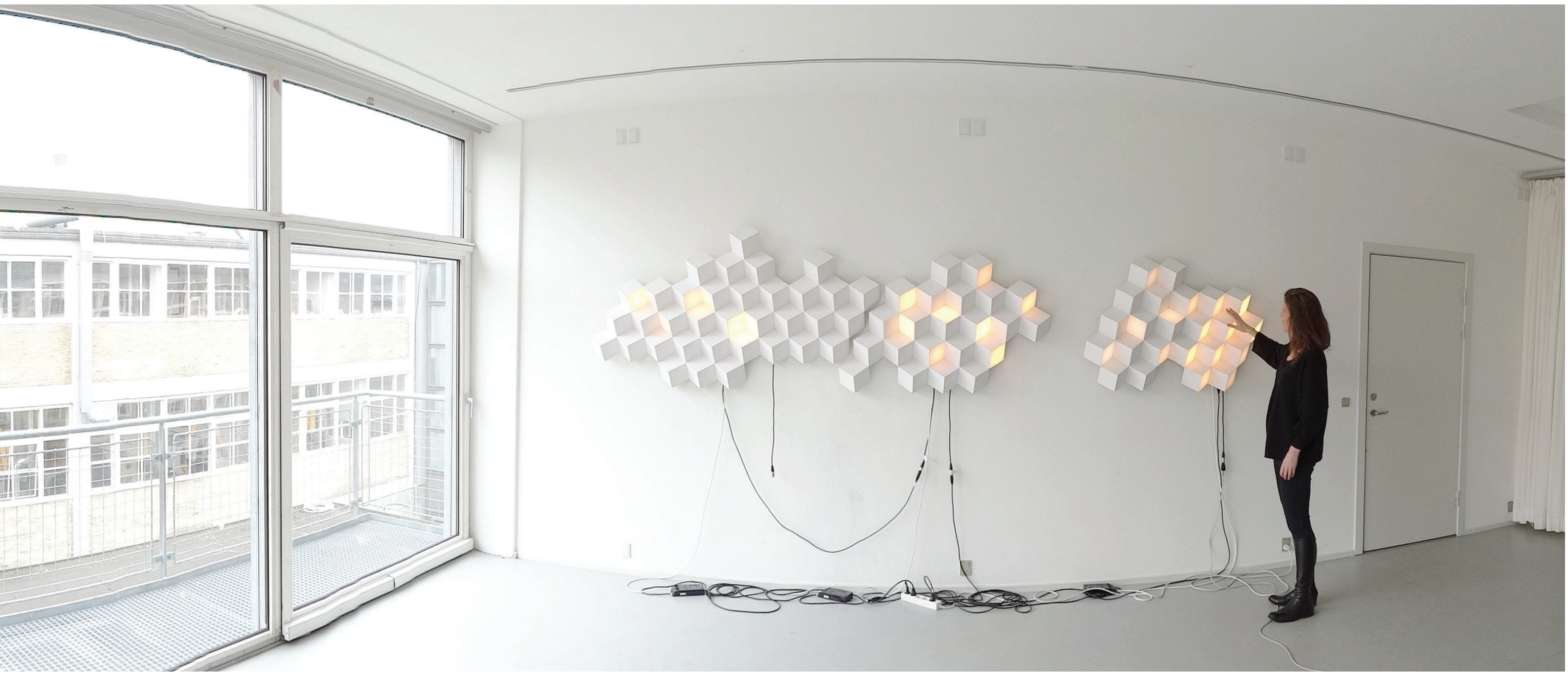

Figure 9. The observational instrument with which one can explore and experiment with the dynamic relations between daylight flux and adaptive lighting driven by a 'digital weather' algorithm.

The test environment is a high-resolution prototype environment where any parameter in need to be included in the investigations are formed into a structural component of the system. In the rehearsals and continuous re-configurations, the parametric capacities are then simplified. The interfaces are made to be guiding for the designer, therefore they have clear visual, auditive, and tactile feedback. (Figure 10). The design of the software is then, very accurately, a proposition for an adaptive system configuration, at least on the level of a coordinated parametric model brought into simplified operations.

The prototypes enable continuous experiential investigation and rehearsal for designers to develop insight into the dynamic lighting as material for lighting design, and develop experiential accounts on adaptive compositions and dynamic. Probing and rehearsing is essential to develop design sensibilities and gradually reach a skilled capacity to engage with adaptive lighting variables and compositional strategies. The prototypes are inhabitable sketching environments, to envision and try possibilities, to explore intents, visions and concepts through systematic probing. (Figure 11 & 12).

Figure 10. (Top) Interfaces to the adaptive lighting system, with clear visual, auditive and tactile feedback. The sliders move, the brightness and colour of the screen changes, all adjustments make particular sounds, and when touched, there is tactile feedback. All this to integrate the complex of dynamic changes in the sensibilities of multimodal engagement.

Figure 11. (Above) Test in an office space using the prototype components to install the functions of the adaptive lighting system. In this environment the changes of light influx during day and night, including light from the houses, cars and streetlight.

Figure 12. (Left) Exploring adaptive compositions with an extended setting, which allows for more complex spatial relations and diversified adaptive lighting compositions. The inhabitants introduce change by entering the room, by reaching the table, by sitting at the table, and similar when he leaves. A larger geography of presence form in space is nuanced in the relational design, and further brought into fluency by the influence of the 'digital weather' algorithm.

References

Battock, Gregory (ed.). 1995. Minimal Art. Berkeley: University of California Press.

Bevins, Jason. 2017. libnoise: Glossary, Perlin Noise. Available from [online]: <http://libnoise.sourceforge.net/glossary/index. html#perlinnoise>. [accessed 16 February 2017]

Bleeker, Maaike. 2016. Movement as Lived Abstraction: The Logic of the Cut. In: Bleeker, Maaike (ed) 2016 Transmission in Motion: The Technology of Dance. London: Taylor & Francis, pp 35-53.

Brandt, Per Aage. 2002. *Det menneskeligt virkelige* (The Humanly Real). Rævens Sorte Bibliotek nr: 55, Copenhagen: Politisk Revy.

Burry, Mark & Jane. 2016. *Prototyping for Architects*. London: Thames & Hudson.

Böhme, Germot. 2013. *The art of the stage set as a paradigm for an aesthetics of atmosphere.* Available from [online]: Ambiences http://ambiances.revues.org/315 [accessed 16 February 2017]

Cherry, Edith. 1998. *Programming for Design: From Theory to Practice.* New York: Wiley.

Gibson, J.J. 1979. *The Ecological Approach to Visual Perception*. Hillsdale, HJ: Lawrence Erlbaum.

Hendricks, Jon (curator) 2008. *FLUXUS SCORES AND INSTRUCTIONS, The Transformative Years, 'Make a salad'.* Exhibition catalogue. Roskilde: Museum for Contemporary Art.

Kaprow, Allan. 1993. *Essays on the Blurring of Art and Life.* (ed. Jeff Kelley). Berkley: University of California Press.

Kuntzsch, D. (ed.). 2009. *Light Perspectives: between culture and technology.* Lüdenscheid: ERCO GmbH.

Lam, William M. C. 1977. *Perception and Lighting as Formgivers for Architecture.* New York: McGraw-Hill Book Company.

Livingstone, M. 2002. *Vision and art.* New York: Abramsbooks.

Maglielse, Remco. 2009. *Designing for Adaptive Lighting Environments*. PhD diss. Eindhoven: Eindhoven University of Technology.

Massumi, Brian. 2009. *Technologies of Lived Anstraction*. Bookseries proposal. MIT Press.

Fludernik, Monika. 2006. *An Introduction to Narratology*. London: Routledge.
Morris, Robert. 1993. Notes on Sculpture. In: Contineous project altered daily: the writings of Robert Morris. London: The MIT Press.

Nöe, Alva. 2006. *Action in Perception*. Cambridge Massachusetts: MIT Press.

Perlin, Ken. 2017. Webpages on Perlin Noice available from [online]: http://mrl.nyu.edu/~perlin/ & http://mrl.nyu.edu/~perlin/doc/oscar.html & libnoise.sourceforge.net [accessed 16 February 2017]

Petersen, Anne Ring. 2015. *Installation Art: Between Image and Stage*. Copenhagen: Museum Tusculanum Press.

Petersen, K, Søndergaard, K, Kongshaug, J. 2015a. *Adaptive Lighting.* Copenhagen: Royal Academy of Fine Arts, School of Architecture, Architectural Lighting Lab.

Petersen, K, Søndergaard, K. 2015b. *An Exploration into Integrating Daylight and Artificial Light via an Observational Instrument*. Copenhagen: Royal Academy of Fine Arts, School of Architecture, Architectural Lighting Lab.

Petersen, K, Søndergaard, K. 2013. *Light as experiential material*. In: Barbara Szybinska Matusiak and Karin Fridell Anter. eds. Nordic Light and Colour. Trondheim, NTNU, The Faculty of Architecture and Fine Arts, pp 47-67.

Petersen, K, Søndergaard, K. 2011a. *Material Evidence as Staged Experientiality.* In: Beim, Anne & Ramsgaard Thomsen, Mette (eds). The Role of Material Evidence in Architectural Research. Copenhagen: Kunstakademiets Arkitekskoles Forlag, pp. 80-91.

Petersen, K, Søndergaard, K. 2011b. *Participation as Medium of Research*. Chapter in the book: Arlander, Annette. ed. Artistic Research in Action. In: Proceedings of CARPA2 (Colloquium on Artistic Research in Performing Arts). Helsinki: Theatre Academy Helsinki, pp. 75-86.

Petersen, K, Søndergaard, K. 2011c. *Staging multi-modal explorative research using formalised techniques of performing arts*. At the conference: EKSIG 2011: SkinDeep- experiential knowledge and multisensory communication. In: Proceedings of the International Conference 2011 of the DRS Special Interest Group on Experiential Knowledge. Farnham Castle.

Sandford, Mariellen R. (ed.). 1995. *Happenings and Other Acts*. London: Routledge.

Schmidt, Ulrik. 2010. *Om det ambiente rum mellem forskelsløshed og figurativitet* (Of Ambient Space between Indifference and Figurativity). In: Henrik B. Andersen. ed. Sliding Zones. Copenhagen: Kunsthal Charlottenborg, pp. 8, 9-10, 7. [translation by the author from danish]

Schmidt, Ulrik. 2013. *Det Ambiente: Sansning, Medialisering, Omgivelse*. [thesis] Aarhus: Aarhus University Press. [translation by the author from danish
Shaker, N. & Togelius, J. & Nelson, M. J. 2016. Procedural Content Generation in Games: A Textbook and an Overview of Current Research. New York: Springer.

Søndergaard, Karin. 2010. *Participation as media: a compositional system for staging participation with reflective scenography*. PhD diss. Caiia, Planetary Collegium, Plymouth: University of Plymouth.
Ursprung, Philip 2016 Studio Olafur Eliasson, An Encyclopedia. Köln: Tachen.

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[i] http://www.danielrybakken.com/Daniel_Rybakken.html
[ii] http://www.openais.eu/en/results/
[iii] http://www.openais.eu/user/file/openais_object_model_annex_(d2.7)_v1.0-pub.pdf
[iv] http://www.openais.eu/user/file/openais_implementation_verification_guidelines_(d2.2)_v1.0-pub.pdf
[v] for instace: http://www.mivune.com/en-US/Home.aspx
[vi] (http://www.smartlighting.org/ , http://www.smart-sensing.org/).

[vii] The perceptual constancies are a wide range of perceptual and cognitive processes that allows us to assume coherence and stability in otherwise variant and fluctuating appearances, e.g. the experience of a wall as one colour even though the luminous level and colour tone across a wall varies dramatically. For an introduction, see Livingstone 2002.
[viii] ole.kristensen.name
[ix] http://www.tate.org.uk/research/publications/performance-at-tate/perspectives/robert-morris
[x] http://www.tate.org.uk/whats-on/tate-modern/exhibition/unilever-series-olafur-eliasson-weather-project