Drawing Inferences: Thinking with 6B (and Sketching Paper)

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Abstract

This article discusses the epistemology of design as a process, arguing specifically that sketching and drawing are essential modes of thinking and reasoning. It demonstrates that the commonly accepted notion of a spontaneous and intuitive vision in the mind's eye—encapsulated in the cliché of the napkin sketch—obscures the exploratory inferences that are made while scribbling with a pencil on a sheet of paper. The draughtsperson, along with their work tools (such as the 6B), modes of notation, specific techniques, and epistemic strategies as well as the resulting design artefacts form milieus of reflection that facilitate complex processes of exploration. Case studies, including the genesis of the Mini by Alec Issigonis, samples of work by Alvar Aalto, and a reinterpretation of student sketches from a classical design study by Gabriela Goldschmidt, serve to illustrate how drawing inferences with pencil and paper occurs.

Keywords Epistemology of designing · Design · Visual thinking · Visual reasoning · Design artefacts · Freehand sketching · Milieu of reflection · Mind's eye · Napkin sketch · Mini · Alec Issigonis · Alvar Aalto · Gabriela Goldschmidt

1 Introduction

‘The story of a cultural icon made of sheet metal begins on a napkin and a table cloth—for this is where designer Alec Issigonis jotted down his first sketch of the Mini’ (Reuther 2016). This is how the press celebrated the origins of the automotive legend on the occasion of its 50th birthday. ‘Small, light, different’¹: in a single stroke of genius, it is

¹Publisher's advertising copy for the exhibition catalogue (Braun (Ed.) 2014).

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suggests that the story of how the Mini came to be needs to be told differently. In the course of her field research at a company manufacturing large industrial turbines, she comes across a technical draughtswoman who has been promoted to chief engineer. The freshly promoted manager has her drawing board taken away from her, as it is assumed that she now has no use for it. She, however, protests strongly and requests that the drawing board be returned to her as a matter of urgency. Without it, she explains, she cannot think: ‘You can’t sit there and wait until you’ve got it up here because it comes through drawing it. And as soon as you start drawing it, you have ideas and changes. You’re erasing it and improving it’ (Henderson 1999, p. 82). Henderson describes drawing as a thought process. In the act of drawing, ideas are generated, discarded and developed further. There is nothing here that points to a ‘readout’ of an image that has emerged fully formed by the power of imagination. The engineer’s words are testimony to an exploratory process of searching and of actively trying out different variants while interacting with the drawing tools available. This description has little in common with the myth of the napkin sketch recounted above. What, though, would that other story of the design process be?

The present essay elaborates the thesis that designing is an epistemic praxis.³ I develop this thesis in two directions. First, I argue that the reduction of design to a single vision that appears before the mind’s eye and is then straightforwardly materialized on a sheet of paper—a common cliché that culminates in the myth of the napkin sketch—is highly misleading and renders the design process as an enigma. Second, I show that the drawing process is a way of thinking supported by its own milieu of reflection, where the interplay of design artefacts, tools and techniques allows the designer to ‘draw’ inferences from her or his sketches.

To begin, Section 2 reconstructs the actual function of the napkin sketch, which must be seen in close relation to the debate about genius in science studies. If the napkin sketch is not taken at face value as a description of the design process but rather as a means of discipline building, then new insights emerge regarding the prominent role of artefacts in designerly thinking processes. As self-generated templates, design artefacts trigger a complex web of inferences, as discussed in Section 3.⁴ A reinterpretation of a series of sketches from a study by design researcher Gabriela Goldschmidt reveals how reflection develops through drawing. As shown in Section 4, however, it is not the drawing alone that affords inferences. The latter only becomes possible through a complex interplay between the person(s) drawing, draughting techniques and tools, modes of notation, epistemic strategies and the resulting design artefacts. As summarized in Section 5, it is this

³ For the notion of “epistemic praxis” and the characteristics of designing in contrast to experimenting, see Ammon 2017a, 2013. The notion of praxis is used here as an overarching term that incorporates habitualized practices as well as non-habitualized actions and serves to integrate techniques, procedures, methods and strategies into the research perspective. The purpose of analysing their epistemic relevance is to explain the specific conditions of processes of learning and gaining insight and thus to achieve greater epistemic progress in the design domain. The adoption of a procedural perspective sheds light on the actual genesis of knowledge instead of merely concentrating on knowledge as an achievement or a result. In order to highlight the differentiation between results (of a process) and the process itself, the term “design” is used to refer to the result while the terms “designing” or “design process” refer to the process.

⁴ This discussion addresses something that can be considered to be, in very broad terms, about a logic of *designing*, i.e. the process of design. The way this relates to a logic of *design*—recently brought into the philosophical debate by Floridi (2017) and dealing with the products of processes (blueprints) rather than with the process itself—should make for an illuminating debate, which unfortunately cannot be entered into here.

resulting milieu of reflection that enables the designer to gain insights about the future product.

It is in no small measure, thanks to Eugene Ferguson, that the huge importance of visualization techniques for the design disciplines came clearly into focus. Providing numerous examples, the mechanical engineer and historian of technology offers an impressive illustration of non-verbal thinking. His influential monograph *Engineering and the Mind's Eye* contains a wealth of technical drawings, from the Middle Ages to the present day (Ferguson 1992). However, his framing of the design process (based on the assumption that a mental image simply gets transferred onto a piece of paper and from there into the minds of others) appears outdated when we look more closely at the boundary conditions of design artefacts. His so-called thinking sketch (ibid, p. 96) can only be fully understood within the broader context and process of its creation, as this essay will show.

2 The Mind's Eye

The narrative of the artistic and technical act of creativity corresponds directly to a similar one in the sciences. Whether we consider Archimedes, Galileo, Newton, Darwin, Poincaré or Einstein—the iconic figures of scientific history are united by the fact that the moment of their discovery has been passed on from one generation to the next in a parable-like story. It was allegedly Galileo's observation of a swinging lamp in Pisa cathedral in 1583 that led to his discovery of pendulum motion, while an apple is alleged to have led Newton to discover the laws of gravity in the 1660s (Arieti 1976, p. 279; Miller 2000, p. 8). One of the most well-known stories of spontaneous discovery involves the chemist August Kekulé. At the Berlin Benzene festival held in Kekulé's honour by the *German Chemistry Society* in 1890, the laureate recounts publicly how his discovery of the molecular structure of benzene had come about in a dream, the atoms gambolling before his eyes (Kekulé 1890, recounted in Japp 1898, p. 100).

Accounts of this kind fail to stand up to closer scrutiny, however. The source for Galileo's discovery of pendulum motion is his secretary, Vincenzo Viviani, whose narrative, among other anomalies, contains a host of chronological errors. It has been proven that Viviani's description arose 75 years after the discovery, at a time when it was necessary to defend Galileo vehemently as the originator of the pendulum clock. The situation is not much better in the case of Newton. A full 20 years after his alleged discovery, Newton had still not developed any concept of a universal gravitational field because for a long time, he had placed his confidence in the Cartesian model. It was not until 1684 that he coined the term 'centripetal force' to describe more precisely the gravitational attraction of two bodies (Schaffer 1994, p. 15f).

What makes Kekulé's story seem especially credible is his public testimony on his own behalf. Yet Kekulé was describing events that lay some 35 years in the past. Psychology research into how false memories arise has been able to reveal how unreliable reports of this kind are (Loftus et al. 1978; Oberauer et al. 2006, pp. 154–158, 177–179). Personal memories are frequently superimposed by other ideas, leading to an altered recollection. Experimental studies show how easily false memories—or even purported memories of events that were never experienced—can come about.

Thus Kekulé's personal testimony should not be understood in isolation from the prevailing model of creative processes of his time. Whereas for a long time, the predominant belief was that scientific discoveries were the outcome of methods that could be learned, the debate shifted in the early nineteenth century.⁵ The concept of the genius began to have its day, with discoveries now being understood as the individual achievements of outstanding personalities. Innovations came to acquire an aura of fascination: they could be traced back to heroes of cultural history whose years of work was condensed into a single, mystically glorified act. The latter is interpreted as the catalyst of a cultural earthquake whose seismic waves ripple out to the present day. Viewed in this light, then, Kekulé's account is not so much an authentic description of events from the years 1855 and 1862. Rather, it is a testimony to how little Kekulé was able to escape the customary view of things in his descriptions—despite being keen to present a neutral account in order to furnish evidence for the rational and laborious process of scientific discovery.⁶

More recent work in science studies has revealed the key mechanisms of these modern narratives of heroism. Historian Simon Schaffer points out that such descriptions are illuminating when they are neither dismissed as myths nor taken literally (Schaffer 1994, p. 16f). The acts of establishing a canon and revering shared heroes fulfil an important social function in the emergence of a discipline. By 1890, Kekulé is already a 'scientific fossil'. Holding him aloft as a genius helped the organizers of the festival to generate a sense of belonging and to secure the status of theoretical chemistry at a time of acute crisis. Kekulé's account breathed new life into imagination and deduction in a field confronted by a predominance of empirical trends in scientific research (ibid, p. 27f.). Schaffer's analyses draw attention to the prevailing research culture, to practices and to instruments, all of which constitute the setting in which new developments occur. This setting makes a key contribution towards stabilizing and standardizing discoveries—and their discoverers (ibid, p. 46f).

Not surprisingly, the history of architecture also has its heroes of spontaneous inspiration. Numerous design myths have been spun around Frank Lloyd Wright, Le Corbusier and Carlo Scarpa. Even Alvar Aalto's pencil—a 6B his second wife Elissa recalls him always carrying around with him—acquired legendary status (Paatero 1993, p. 21). Aalto used the famous Koh-i-Noor Hardtmuth lead in a clutch pencil (Die keramische Bleistiftmine 1958; Petroski 1989, pp. 161–163; Krasny 2008, pp. 151, 154). Clay is mixed in varying quantities with graphite powder to obtain different grades of hardness. Grades of hardness, in turn, influence ways of working and the characteristics of a drawing. While the medium grades are used first and foremost for writing, hard leads are used for technical drawing, as they retain their fine point for a long time, thus enabling exact lines to be drawn. The 6B is one of the very soft leads, which leave behind a very dark black line and enable rapid and intuitive working. It is the line that gently fades away at the edges which characterizes Aalto's late drawings.

⁵ While enlightenment philosophy assumed (with Bacon, Descartes, Locke and Leibniz) that discoveries occurred by following certain rules, the debate took a new turn during the Romantic period; cf. Laudan 1980; Schaffer 1994, p. 28; Schmidt 2004a, b.

⁶ Kekulé 1890, cited in Anschütz 1929, pp. 939–945. Subsequent research suggests, instead, that the discovery of the structure of benzene should be understood as a multi-layered process in European chemistry research that occurred over many years and in which a range of actors were involved (Rocke 1985, pp. 364–371; Wotiz and Rudofsky 1984, p. 721; both cited in Schaffer 1994, p. 26f.).

The pencil here becomes a seismograph of reflection, the emerging line a trace of the drawing hand.

It comes as no surprise, therefore, that Aalto should have left behind an especially impressive example of the napkin sketch. It is one that documents the origins of the Church of the Holy Spirit in Wolfsburg. The history of how it came about was recorded 34 years after the event in a commemorative publication produced by the parish council. Aalto, who had won the competition to design Wolfsburg's cultural centre, was staying in the city. He was persuaded to take on the job during a meal in the city's Ratskeller in the summer of 1958. As an anonymous witness present at the time recounts, he reached for a napkin and sketched a cross-section of the church's interior (Fig. 2), commenting as he did so that, in terms of acoustics, this was the most advantageous interior conceivable (Kirchengemeinde Heilig-Geist 1992, p. 6). The paper artefact recorded the main ideas of the later building and became a relic documenting the moment of inspiration.⁷

This apparently sudden stroke of inspiration is relativized, however, when one considers the broader context. Church architecture was anything but a marginal activity in the work of Aalto. His catalogue of works lists 37 projects involving religious buildings, 22 of which were church designs; 7 of these came to fruition (Brülls 1998, p. 345). Planning for the Church of the Holy Spirit was immediately preceded by the construction of two churches in Finland: *The Church of the Three Crosses* in Vuoksenniska near Imatra and a church in Seinäjoki. As building conservationist Holger Brülls explicates in his comparison of Aalto's churches, the upwardly sloping ceiling behind the altar and the trapeze-shaped floor plan are features that characterize almost all of Aalto's church designs—so it is hardly surprising to find them clearly marked on the aforesaid sketch. Aalto generally justified the shape by reference to acoustic requirements (Brülls 1999, p. 9). In that same year of 1958, Aalto had participated in an international church design competition in Denmark, the basic design ideas for which he was now able to put to use in Wolfsburg (ibid, p. 9f). Given his many years of preoccupation with the subject, then, the documented napkin sketch is anything but a sudden, spontaneous design idea. Instead, it is much more likely to be linked to the afore-mentioned competition entry, whose 'ideal design' (ibid, p. 9) included tried and trusted features from previous plans. During his business lunch, then, Aalto refers to this previous work to convince his potential clients of his suitability for the job. Just how far removed this sketch is from the fully elaborated design is revealed by comparing the sketch to the later floor plan (Fig. 3). The biggest area of overlap between the two is found in the church's structural shape, which can mainly be traced back to earlier designs. As far as the overall layout of the community centre is concerned, however, the sketch contains only a vague intimation of a right-angled structure, reminiscent of monks' cells, which follows the alignment of the outer wall of the church. In the fully elaborated plan, this idea has given way to a honeycomb-shaped set of interior spaces

⁷ Typical again are the contradictory sources given for this. Whereas Nerdinger speaks of the napkin having been looked after by the church (Nerdinger (ed.) 2003, p. 3), the article written by building conservationist Holger Brülls states that the document has unfortunately been lost (1999, p. 9). In contrast to this, curator Reinhard Roseneck presents a depiction which he attributes to the city of Wolfsburg (1999, p. 147), while architectural historian Susanne Müller, in her highly detailed account of the origins of the Holy Spirit Community Centre based on correspondence, files and interviews, does not even mention the making or the existence of the sketch (2008, pp. 128–138).

Fig. 2 Napkin sketch of the Church of the Holy Spirit in Wolfsburg by Alvar Aalto, 1958. (Roseneck 1999, p. 147. © Alvar Aalto Museum)

to which an additional building complex is grouped in the upper third of the drawing—which does not appear at all on the napkin sketch.

If we heed the lessons of science studies, then, scenarios of this kind betray less about the actual process of designing than about the way a discipline is constituted. In the emergence of the modern professions of painting, sculpture and architecture, the freehand sketch becomes a sign of differentiation from purely artisanal tasks. As described by the influential Renaissance theoretician Giorgio Vasari, their common denominator is the art of drawing or ‘disegno’. ‘Disegno’ here becomes not just a synonym for artistic inspiration that takes shape in the act of drawing but also a tool of communication, heralding a new organisation of the workshops based on a division of labour.⁸ These ideas were prefigured by Leon Battista Alberti in his architectural treatise *De Re Aedificatoria*. There, he marks a division between the artisanal work of building and the intellectual task of planning. The latter is accorded much greater value and is declared to be the real task of those who create architecture (Alberti [1485] 1726, pp. 1–2). Subsequent to Alberti’s intervention, design comes to represent the epitome of architecture (Kruft 1991, p. 53). The associated significance of the freehand sketch comes to be inscribed into the curricula of the newly emerging educational institutions such as the *Accademia di San Luca* in Rome and the *École des Beaux Arts* in Paris. The spontaneous freehand sketch becomes a mirror of the artist-architect—a symbolic meaning that has survived to the present day (Nerdinger 2003, p. 57).

This sheds light on the complex role of the napkin sketch. The saga of the napkin sketch is one we should not take at face value; rather, we need to understand it in terms of the function it serves. The glorification of the freehand drawing enables a certain disciplinary stabilization and consolidation. Constructing scenarios around a few heroic figures serves to create certain fixed points of orientation for the community as a whole. Narratives of this kind are poorly suited, however, to reveal what actually goes on

⁸ Burioni (ed.) 2006, p. 7; cf. Panofsky 1960, p. 36f.; Kemp 1974. The artist myths associated with the term *disegno* have their roots in antiquity (Nerdinger 2003, p. 56).

Fig. 3 Floor plan of the Holy Spirit Community Centre, Wolfsburg (Roseneck 1999, p. 147. © Alvar Aalto Museum)

during the design process. Drawing on insights from the history of science, it can be assumed that behind the scenes of a design there are multi-layered processes at work, shaped by different actors as well as different technical and cultural settings. The differences between the design disciplines are also enlightening in this regard. Whereas the celebrity cult in architecture and design creates a prominent role for the napkin sketch, it is much less familiar in the planning and engineering sciences, where teamwork is emphasized as opposed to focusing on a single personality.

If, however, we compare the emergence of Aalto's Church of the Holy Spirit with Kekulé's discovery of the structure of benzene, the two stories differ in one essential respect. While Kekulé's account is based on a vision, the creation of the Church of the Holy Spirit is all about an artefact. This small difference harbours a crucial clue: it suggests that design artefacts play a prominent role in the process of making things. Their importance appears to be so great that they are glorified in the form of the napkin sketch in order to preserve the traces of that moment of emergence. High time, then, to take a closer look at the role they play.

3 Playful Inspiration and Visual Inferring

Aimless scribbles on paper that suddenly start to make sense and provide the key to the next stage of development—design researcher Gabriela Goldschmidt takes what looks like playful inspiration as an opportunity to study forms of visual inferring. Her interviews with architects offer clues as to how intuitive drawing methods deployed in the early phase of a design are used deliberately to generate ideas. 'I can't get very far just thinking about it without drawing something', states one respondent, continuing: 'I like to have a lot of lines on the page. I like fuzzy stuff. I can see things in it more than I can in hard-lined things. So, sometimes I just get a lot of lines out and then I start to see

things in it. A lot of times I pick up things I think are important' (Goldschmidt 1994, p. 168; cf. Goldschmidt 1991). For this architect, the process of thinking only unfolds as she draws. The blurring of the lines drawn over and next to one another helps her to discover a starting point in what she has drawn. Repeatedly starting over again is an important part of this. 'When I sit down to work, it's hard', another interviewee explains. 'When I first start, I do a lot of drawings. I don't understand what I'm doing until I draw it a few times, and then it becomes clear to me what I'm trying to do, and then I can begin to work on it' (ibid, p. 168f). Sketching helps him to overcome the difficulties he encountered at the beginning. By drawing different versions of the design, his understanding improves and he gains a clear idea of where the problems lie.

What interests Goldschmidt is how this kind of approach initially appears intuitive yet is simultaneously rational and systematic. In a detailed study, she explores the early stages of development of a design produced by one of her students (ibid, pp. 166–174). Although his existing design had been praised by his supervisors, Larry is unhappy with the result. At this point, he has already produced a fully elaborated proposal for the design task. A kindergarten is to be developed on an L-shaped piece of land with a slight upward slope. Larry is not satisfied with his modularized solution, based on the grid of a cube—it reminds him too much of designs produced by some of his fellow students. Driven by the desire to find a new starting point, Larry sits down in front of a blank sheet of paper, pencil in hand. Almost out of embarrassment, he begins to decorate the left- and right-hand edges of the page with his signature (Fig. 4a)—continuing for so long that the pencil marks eventually detach themselves, completely unexpectedly, from any connection with his signature and develop a life of their own as graphic figures. Looking at what he has drawn, Larry discovers to his surprise that the intertwined characters have created an enclosed space. He takes a soft pencil and goes over the lines again with a full, dark stroke, this time to explore them as a spatial situation. Becoming curious, in the upper right-hand corner he tests the arrangement in the measurements of the plot (Fig. 4b). Encouraged by the result, he now starts in the middle of the page to explore the spatial structure. By enlarging the shape considerably,

Fig. 4 Larry's first sketch (Goldschmidt 1994, p. 168. © 1994 Published by Elsevier Ltd.)

Larry is able to examine the interplay between parts of the building. Being highly familiar with the boundary conditions on account of his prior work, it is easy for him to include a number of requirements for the space allocation at this early stage. The thick, flowing lines explore the outline of the building. Extending them offers a large amount of leeway to interpret forms and prevents Larry from committing himself too soon in his exploration, which he now pursues more forcefully by pencilling over the existing traces several times.

As the shape proves its worth and becomes stabilized in the course of working, it is time for Larry to reach for a second sheet of paper (Fig. 5). The soft, curved shapes open up a new way to approach the room layout. He starts to draw again. The character of the sketch now changes quite markedly. The leeway for interpreting the lines is reduced as they become sharper and clearer in their thrust. Initial elements of standard notation for architectural plans start to appear, even if they play a subordinate role as yet. The lines turn into walls, staircases, pathways, and vegetation. The sheet of paper bears testimony to a host of questions that Larry is addressing in the process of drawing. He now tries to work out specifically how the building can be fitted into the land available and how the sloping ground impacts on the spatial layout. How can the land be developed, where are steps located, where is the main entrance? How will each room be used and how can they be meaningfully arranged? Whenever necessary, supporting calculations are done at the paper's edges.

In the third sketch of the session, the character of the drawing has changed yet again (Fig. 6). Compared to the second sketch, it is even more abstract and more schematized in terms of notation. The lines are clear, and the space available for making strokes has been considerably reduced, now existing only where new ideas about certain problems are being tested, such as the arrangement of steps in the bottom left-hand corner.

Fig. 5 Larry's second sketch (Goldschmidt 1994, p. 170. © 1994 Published by Elsevier Ltd.)

Fig. 6 Larry's third sketch (Goldschmidt 1994, p. 171. © 1994 Published by Elsevier Ltd.)

Besides exploring a few details, on this page, Larry concentrates on construction issues. Walls are represented as black lines, the underside of the roof as dotted lines. Supports, marked as small solid circles, appear as a theme, because the weight of the roof needs to be distributed. Again, calculations at the page's edges complement the exploratory drawing. Confirmed in his approach, a few important design basics are now in place. In order to examine further issues regarding the spatial layout inside and outside the building, Larry switches to modelling.

Very much later, during the final design review, Larry presents his elaborated plans and presentation model. His proposal is captivating on account of its soft, organic shapes and flowing sequence of rooms. Explaining his design, Larry mentions that he chose this kind of architecture because he felt that straight lines and right angles were too hard and aggressive for the small children who were later to use these rooms. In his reconstruction of the design process, the signature no longer played any role at all—he had (as a subsequent evaluation of the study revealed) simply forgotten them. In his retrospective interpretation of the design process, the change of course was preceded by a new design concept that enabled him to re-structure his approach (Goldschmidt 1994, p. 172). The actual course of events notwithstanding, Larry's memories had been superimposed by the commonplace schema of an ideal-typical design process—an effect we encountered previously in Kekulé's description.

How, though, can something as coincidental as a randomly scribbled combination of letters become the catalyst for a newly developing design? Surely other sources of inspiration could also have brought about a similar effect: a stroll in the countryside, an evening at a concert, or a look through one's own collection can all be a playful way of breaking through an existing, unproductive state of thinking and of re-structuring it.

Leaving something one has produced alone for a while so that existing associations can weaken and new ones arise can be conducive, as research on creativity has found. Often a sense of ‘aha!’ comes with the new jumping-off point and is experienced consciously as a moment of insight (Förster and Denzler 2006, p. 449; Öllinger and Knoblich 2006). The reason why the signature was so important for Larry in developing his design is because their soft shapes spoke to his desire for change and helped him to liberate himself from right angles and a rigid modular approach; it was a desire he was not even conscious of at that point in time. Indeed, this is also why, for Goldschmidt, the sketch is such an important instrument in developing a design: as a template produced by the designer her- or himself, it is able to make precisely such non-conscious, implicit influences visible (Goldschmidt 1994, p. 170).⁹

Accounts of visions appearing before the mind’s eye serve to mystify and glorify such processes. To show just how misleading such glorification can be, let us consider a simple scenario. Assuming it really is just a case of producing a readout of an image already present in the mind’s eye: the sketch would record what the mind’s eye saw in order to make this vision available to others—a conceptual idea in material form. Rough-and-ready pencil drawings are what Larry has produced; we see dark lines on a light background, some of which have consolidated to form regions. In those places where the sketches become more architectural and deviate from being pure explorations of shape, they transition into ideas for the floor plan based on a two-dimensional projection. Larry’s pencil strokes are still rather awkward in some places; an inexperienced draughtsman is clearly at work here. What must have gone on in his mind’s eye as he was producing these sketches? If we could look inside his head, would we find mental images comprised of lines in spatially extended black-and-white look with no sense of depth?

Research conducted by experimental psychologists Barbara Tversky, Mary Hegarty, and Andrew Stull closely analyses forms of visual-spatial thinking; as they emphasize, mental images are similar to what we experience with our eyes (Tversky 2005; Hegarty and Stull 2012; cf. McGinn 2004, pp. 42–47). It is much more likely, then, that what is appearing before Larry’s mind’s eye is a succession of rooms, in many respects, reminiscent of his everyday perception of buildings. Depending on how well-trained his spatial imagination already is, he can wander through parts of the yet-to-be-built edifice. He ‘sees’ the rooms as atmospheric impressions linked to particular angles and influenced by specific lighting situations, materials and colours. Perhaps Larry is even able to fill the rooms with children and to imagine noises and smells. He steps into the main room, revealing a play area flooded with light. Laughter can be heard, the wood of the mounted furniture warms up with a soft cracking sound, and the air is filled with the fine essential oils of the resin. Larry feels the soft tread of his footsteps on the linoleum floor as he slowly approaches a round podium on whose steps children are at play. Moving mentally through the space in this way gives him a sensed impression of the future components of the building: pieces of scenery, blurred and fragmentary, that may serve to test the effects of spatial arrangements and materials.

Even if we are unable to look inside Larry’s head, this simple thought experiment shows how little an imagined vision of the future building has in common with the

⁹ This is different again from the ‘process of drawing the self’ (*Verfahren der Selbstaufzeichnung*) (Wittmann 2009).

pencil sketch's black lines on a white background. Yet, if we were to take seriously the theory of a readout procedure, this is precisely what should be the case. What Goldschmidt's study reveals instead is that the very opposite is the case: that—to retain the information technology metaphor—it must be a read-in rather than a readout process. The exploratory efforts she documents illustrate impressively that Larry possessed no internal picture of the future building. What he starts with is a blank sheet of paper on which, using a pencil, he begins to sketch, driven by the desire to liberate himself from his earlier design. It is only as he is sketching that new ideas are generated. His musings have no object at this point and so there is nothing to behold—precisely because this object has yet to be developed. Drawing becomes a key technique for developing a notion of the future artefact. In his absent-minded scribbling, Larry discovers clues, which, bit by bit, he is able to build on.

The example with Larry shows how it is the process of drawing that generates a vision. The act of sketching sets off a complex chain of interactions between the faculty of imagination and something which design scholar Donald Schön has described as the 'materials of a situation' (Schön 1983, p. 78). According to Schön, the design process becomes a conversation with the design artefacts in which the materials 'talk back' (ibid, p. 79). Sketches put up resistance and thus challenge designers to produce a response. Schön is insistent here that drawings have a life of their own. This is how the design develops, stroke by stroke, with exploratory movements and in multiple iterative loops—aimless scribbles suddenly revealing something designers find they can work with. But it is not just the movement of pencil on paper that is important: stopping and pausing is just as important. In looking at what has already been put down on paper, previously unnoticed facets come to light that can serve as the next starting point. Should the developing sketch be heading nowhere, a process begins which Schön calls the 'reframing of the problem' (ibid, p. 85). The designer looks for a new point from which to address the question anew. As in one of Schön's case studies where competing design requirements are blocking progress toward a solution, this new starting point may be an important design parameter. In a redraft, this new starting point becomes the launch pad for weaving a web of inferences. As in Larry's case, though, it may equally well be a blank sheet of paper and a playful session of sketching. What emerges from this is, in Schön's words, 'a web of moves, consequences, implications, appreciations, and further moves' (ibid, p. 94).

This is why Schön describes the process of designing as a process of reflection or, more precisely, 'reflection-in-action'. The phrase recalls the work of John Dewey, one of the foremost thinkers to address the praxis of thinking from a philosophical perspective. Much of what Dewey includes within reflective thinking—those processes involving a purposive, conscious quest for insight—is what we see in Larry's drawing processes. The process of thinking is more than a 'sequence of ideas' (Dewey 1910, p. 2). According to Dewey it is a '*con*-sequence', a 'consecutive ordering', '[t]he successive portions of a reflective thought grow out of one another and support one another' and display a considerable degree of internal cohesion (ibid, pp. 2–3). One step follows the other and the outcome becomes a new starting point for the next one. 'Each term leaves a deposit that is utilized in the next term', stresses Dewey (ibid, p. 3). Nothing was to be taken as given too soon; rather, '[a]ctive, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it, and the further conclusions to which it tends constitutes reflective thought/ (ibid, p. 6).

The quest for insight is borne by acts of inquiry and testing (ibid, p. 30). Such practices of thinking make it possible to devise a solution to a problem. Probing and exploring, showing and doubting, observing and inferring, varying and judging: all these elements that constitute the ‘how’ of thinking come to light in Goldschmidt’s study of the process of drawing.

One issue should be noted at this point. The way students such as Larry go about their drawing is certainly different from the way experienced professionals do so. Their faculty of imagination being less schooled, work tools such as the sketch become more important. As a designer’s professional skills grow, the importance of drawing during the exploratory stages may recede. Certainly, part of the reason for this lies in having developed a more finely-honed imagination. Where this is the case, it is simply no longer necessary to work things out in detail on paper. Elissa Aalto recounts, for example, that in his old age, her husband worked less and less with sketches, instead doing much of his work in his head (Paatero (Ed.) 1993, p. 21). Another reason is that, after many years of professional practice, experienced designers are able to draw on previous design solutions. These earlier designs constitute a treasure trove of experience that can be drawn on and applied to new tasks. However, such observations should not tempt us to underestimate the epistemic function of the process of drawing. The fact that this process can be cut short under certain circumstances serves to further underline its fundamental importance.

4 Thinking by Sketching

Schön’s emphasis on the ‘materials of the situation’ (1983, p. 78) give us an important clue as to why design artefacts play such a preeminent role in thinking processes. What remains unclear, however, is how visual inferring takes place in reference to those materials. The situation changes when we switch to the meta-level of the creative process and interpret the ‘residues’ from the drawing process as prerequisites for visual inferring. The traces on the paper can now be construed as traces of the conditions of production. Although the abductive inferential schema is not adequate to describe Larry’s inferring-by-drawing, it can provide access to the medial preconditions for the process of emergence. The pencil traces provide information about the conditions in which they arose. The design artefacts enable us to discover something about how the tools that generate them have been used and about the materiality of these tools. Being inscribed into the products, the milieu of reflection can be reconstructed. It is through the ‘traces of’—that is, those traces the milieu leaves behind in the results—that we also discover something about the ‘traces for’, as philosopher Christoph Hubig puts it—about the broader conditions established by the milieu and through which it opens up space for thinking.¹⁰ It is here that the trajectories are set for (re-)working and exploring, a means to guide the thought process. As we shall see in this final section,

¹⁰ Hubig 2006, p. 148—although Hubig speaks here merely of ‘technical mediality’ and not of a milieu of reflection. Philosopher Sybille Krämer highlights the materiality of the medium as the foundation for a “surplus” of meaning’ (*Überschuss an Sinn*) and an “added value” to meaning’ (*Mehrwert an Bedeutung*) (1998, p. 79). Daniel Gethmann and Susanne Hauser (2009, p. 9f) and Robin Evans ((1986) 1997; 1995) refer to the mediality of design tools from the perspective of architectural theory.

then, the complex interrelations between tools, techniques and design artefacts constitute an explanation for how drawing-based thought acts are validated without reference to the standard schemata of logic.

It is only by adopting this approach that we finally learn more about the actual thinking in Ferguson's so-called thinking sketches. In his monograph *Engineering and the Mind's Eye*, Ferguson distinguishes between 'thinking' and 'prescriptive' sketches (Ferguson 1992, p. 96f). In doing so, he draws attention to an important functional distinction. Whereas the 'thinking sketch' is based on a generative activity—in other words, sketching that is done to engender ideas and develop thinking, the 'prescriptive sketch' is instrumental in character. In the case of the latter, the main purpose is to convey information and provide instructions for performing certain tasks—as, for example, when the sketch becomes the basis for a technical drawing or serves as a direct set of instructions for executing the construction.¹¹ The one function usually flows seamlessly into the other. Often enough, a design will be developed initially on a piece of paper; when the design stands, this same piece of paper serves as a guide for its elaboration.

In the case of Larry's drawings, we have a paradigmatic example of a thought process conducted through drawing, that is, of a generative act. What remains from this process are three sketches. What can these traces of the act of drawing tell us about the practice of thinking with pencil (or pen) and paper? We do not know whether Larry actually used a 6B for his first sketch (Fig. 4). But the characteristics of the sheet of paper point toward the use of a soft pencil. The lines are lush and of a very deep black. They stand out prominently against the light ground of the sketching paper. The presence of the same colours and the proximity of certain image elements to one another reinforce the impression of interconnected gestalts: such shapes become identifiable where the lines join up and mark out a shared region.¹² This is what it must have been like for Larry as he sketched his signature at the edge of the piece of paper. All of a sudden, his eyes can make out something different: he no longer perceives letters but rather areas and outlines emerging from intertwined lines.¹³ Surprised by this, he begins to analyse the formations on the paper; in the course of doing so, he will cross one of them out. When Larry begins to draw again in the middle of the page, the lines have long since become form-giving walls that subdivide the emerging space into different zones.

These processes are set in train by the characteristics of the work tools whose particularity now comes to light. One striking feature is that the pencil marks smudge; they remain fuzzy at the edges and thus demand no precise definition. Everything this sketch conveys can remain vague, without fixing or defining anything too soon. Broad pencil marks open up an array of options for interpretation which are further enhanced

¹¹ This differentiation is based on functions of the active image, which can display a generative and an instrumental operativity (Ammon 2017b; cf. Ammon and Capdevila-Werning 2017).

¹² The process of interpretation can be explained by reference to gestalt principles. These include the principle of *pragnanz*, similarity, good continuation, proximity or nearness, connectedness, common fate, meaningfulness or familiarity (Goldstein 1999, pp. 181–184).

¹³ This is an example what the philosopher Ludwig Wittgenstein called 'aspect-dawning' or 'change of aspect' (*Aufleuchten eines Aspekts* or *Aspektwechsel*). Influenced by gestalt theory, specifically by Wolfgang Köhler, Wittgenstein argued that certain schematic drawings invite the viewer to see them under more than one aspect (Wittgenstein 1967: II 194; cf. Glock 1996).

by drawing over them again and again. The materiality of the pencil directly supports the current stage of reflection. It is not clear as yet how the spaces will be arranged and where exactly the walls will be. At this point, such decisions would overburden the process. Thanks to the pathways of reflection built into the tools, these questions can be deliberately left unresolved without hindering the ongoing process of development.

The greasy, soft lead of the pencil enables the sketching hand to glide smoothly over the paper. The movement of the hand, the emerging traces on the paper and the flow of thoughts form a unified whole. Elusive thoughts are put down on paper and made available for re-working. Sketching helps the designer to work rapidly, erratically and associatively. As a procedure for recording ideas, it leaves considerable leeway for future elaboration. There are hardly any rules to apply—characters (as when scribbling a signature), graphic shapes and areas, and architectural notation are all allowed (cf. Goldschmidt 2017, pp. 82–83). The transition from one mode of representation to another is fluid, enabling boundaries to be crossed. The same line can be a letter here or a shape there, and elsewhere, it may be a wall. Rules can be formed ad hoc, to make what has been drawn available to fresh interpretation. A character is transformed into a spatial boundary if the letter's inscription is read as a projection line in a two-plane projection: all at once a rough-and-ready scaled floor plan for a building emerges.

A comparison with Larry's second and, in particular, his third sketch (Figs. 5, 6) shows just how closely the draughting system and the type of thinking are interrelated. As Larry begins to develop the floor plan, graphic gestalt becomes less important; the drawings become more schematic and more similar to the mode of notating plans. Symbols and other representational conventions acquire greater importance, and the process becomes more rule oriented so as to address a range of architectural issues. The draughting system enables a high density of information to be gathered together. Externalizing the process of deliberation on paper frees up head space and creates more thinking capacity (Tversky 2005; Hegarty and Stull 2012). At the same time, the pictorial presentation enables elements that had previously been dealt with separately to be perceived simultaneously. When notated one after another in the process of drawing, they can be dealt with as part of the whole in subsequent work phases. This is essential for working on complex design problems where a large number of factors and often contradictory requirements need to be brought into relation with one another. In pictorial presentation, they become amenable to analysis, and the overall consequences of presuppositions can be clearly surveyed.

It makes sense at this point to change to a harder pencil (or, if not available, to sharpen the pencil). We can see from the later sheets how Larry's technique changes. The marks become narrower and more well-defined, exploratory moves turn into fixed decisions. The movement of Larry's hand can also be expected to change at this point. Instead of dragging the slanting pencil across the page with a full swinging motion, he will now hold the pencil relatively straight. This gives him more control over the line to be drawn; the pace of drawing slows noticeably in the process. Both the precision and the density of the information conveyed increase. The materiality of the tools and the draughting techniques form a unified whole here, simultaneously laying down the pathways along which the space for thinking evolves.

The manipulation of the artefacts sets cognitive processes in motion, which enable inferences to be drawn, judgements to be made and decisions to be reached. This does not happen in accordance with classical logical operations,

yet it does not mean they are irrational. What Umberto Eco has identified in relation to creative meta-abduction now becomes fundamentally significant for inferring-by-drawing, namely, epistemic strategies and heuristics which are deeply rooted in experiential knowledge and which create relationships and connections in the reflective process of drawing.¹⁴ Even just selecting the right tools and the corresponding milieu of reflection for the problem at hand is a key design strategy (Ammon 2017b, pp. 203–204; cf. Hubig 2006, p. 213). By working with a soft pencil on paper, Larry is able to concentrate on issues to do with the shape of the building and the layout of the rooms, offering him a strategy for simplification. Varying the lines and repeatedly sketching certain shapes, which often differ only in minimal nuances, enables comparison. In applying this strategy, Larry is able to work out where strengths and weaknesses lie, with criteria and their weightings being formed spontaneously in the process. We also find a strategy of standing back and looking anew in the series of sketches: contemplating his signature, Larry picks up important clues for restructuring the design (Goldschmidt 1994; cf. Goel 1995; Suwa and Tversky 1997; Tversky and Suwa 2009).

This cursory analysis demonstrates not only how much the materiality of traces can reveal about the tools that made them but also the extent to which the materiality of the latter influences the emerging conceptual space. Changing the hardness of the pencil can thoroughly transform the milieu of reflection. An arena opens up between designers, design artefacts, drawing tools and modes of notation in which thought processes develop, guided by epistemic strategies. The specific conditions of the milieu set the framework for reflection, thus intervening as a regulating influence. Characterized by certain rules of application and representational techniques, the milieu guides the drawing-based inferences through subsequent stages of adjustment and simultaneously validates the accompanying deliberations.¹⁵

5 Conclusion

Milieus of reflection allow the designer to literally draw inferences. Aalto's choice of a 6B at the start of a design process is a deliberate decision to lend optimal support to his exploration of the as yet non-existent. The pencil and the corresponding materiality of the paper open up an arena where thought processes evolve in interaction with the emerging design artefacts (in Aalto's and Larry's case, a series of sketches). The lines

¹⁴ Eco 1983, p. 207; cf. Hubig 2006, p. 206f. For image-based epistemic strategies, see Ammon 2017b; for the concept of strategies and heuristics in general, cf. Hertwig 2006; Hertwig and Todd 2002.

¹⁵ The rules of application and representational techniques in the early design phase (which characterize Larry's series of sketches) are necessarily less pronounced than in other draughting techniques. As Gabriela Goldschmidt (2017, p. 82) points out, manual sketching is characterized by 'minimal generation rules' in order to allow a high speed of production and to maintain the flow of deliberations. The interplay between draughting system and validation becomes more explicit when we look at elaborated projecting techniques such as orthogonal projection and perspective. By combining different planes of projection, for example, it becomes possible to continually check the drawing results. Computer-aided design techniques nowadays allow partially automated testing and trouble-shooting by means of so-called clash detection (see Ammon 2017b, pp. 198–199).

on the paper ‘talk back’ to the designer at the very moment of their creation and trigger insights that were not there before. The result is a complex web of inferences through which the consequences of assumptions (in the form of lines) are tested (by adding new lines), variations are explored (by superimposing lines that differ in nuanced ways), and potential solutions are weighed against each other (by comparing formations of lines with one another).

However, the pencil corresponds not only with the materiality of the paper but also with an appropriate system of notation that directs the focus of reflection. Whereas the soft and greasy 6B enables quick and rough investigation of *gestalts* of a future building by concentrating on graphic forms, the firm 2H requires a slow and controlled draughting technique, which brings together complex strands of information by superimposing upon one another various notational elements, from symbols to numbers. This, in turn, makes it possible to relate divergent findings to one another and to cross-check them. The examples offered in the present study refer mainly to the rather old-fashioned tool of a pencil used for freehand sketching. Yet, the underlying claim of the study is not limited to this specific milieu of reflection. We can expect similar findings when we look at design techniques based on information technology or hybrid forms based on a mixture of analogue and digital tools. The question that then follows is how the resulting milieus of reflection differ in their epistemological performance with regard to the benefits, constraints and biases embodied in the technology—a challenging question which must be left to future research.¹⁶

To conclude by stressing the point once more, the present study does not deny the occurrence of spontaneous visions and insights in design processes—as an important ingredient of learning and creativity, they certainly do occur, as in any other exploratory practice, from the arts through to the sciences. The danger lies rather in reducing the design process to these occurrences and thereby generating a profound misconception of their epistemological potential. Designing can only be recognized as an epistemic praxis when we give up common clichés, such as those encapsulated by the napkin sketch. Once we do so, a close look at drawing tools and their associated techniques and products reveals a rich and fascinating field of research, which is not only able to tell us more about thinking processes in design but also invites us to adjust our understanding of inferring *per se*.

6 Addendum

The question that finally remains is how the story of the Mini’s origin, recounted at the start of this article, should actually be told. Ferguson’s account mentions a third form of sketch in addition to the two described above, namely, the ‘talking’ sketch. This one is not associated with any new function; instead, the phrase points to the use of sketches in communicative situations. Up to now, we have encountered sketching as an

¹⁶ This also includes a comparison of milieus of reflection based on techniques drawing in 2D (images), 3D (scale models) or 4D (simulation); for some tentative deliberations on this, see Ammon [2017b](#), [2017c](#). Especially illuminating for the epistemic capacity of images is Krämer [2016](#); for an epistemology of the diagrammatic in relation to drawing and engineering, see, e.g. Magnani [2001](#), Stjernfelt [2007](#).

individual thinking process. However, the practice of drawing in order to think can also take place in a shared context, for the purpose of bringing different people's expertise together in a sketch. This generative use arises in meetings where there is often a fluid transition between re-working a particular stage of planning and developing the design further. Spoken communication becomes less important here; ideas are shared mainly via the sketch.¹⁷

In communicative situations, however, the instrumental use of the sketch acquires greater importance. The main aim here is to convey information, to convince one's counterpart or to explain something to them. To take one of Ferguson's examples, when a product developer is making no headway with his explanations, he reaches for pen and paper. To illustrate to the client how the force of a paper nip in a computer printer can be transferred equally over a relatively small roller, the designer produces a sketch (Ferguson 1992, p. 101). The talking sketch becomes an instrument for showing the current stage of planning.

It is this kind of situation that will have prompted the napkin sketch of the Mini. The explanatory comments scribbled at the edge of the image, used to give an uninvolved person greater understanding of the drawing, are a clear indication of this. When Issigonis was given the job of developing a new small car, he already had many years of work in this area to look back on. He had concerned himself at length with different kinds of front-wheel drive and a changed engine position. The sketchbook, which served him as an important thinking aid in the development of the XC/9003 (later to become the Mini), opens with a few general considerations of dimensions and weights (Bardsley 2005, p. 191). Countless drawings and models preceded the creative act before the insights presented in the legendary sketch could become consolidated. To present a stage of development of this kind, it had been necessary to pool the expertise of many specialists, to deliberate exhaustively over constraining conditions and parameters, and to devise, improve and discard proposals.

An inquiry made to the *British Motor Industry Heritage Trust*, which holds Issigonis's sketches, brings us back down to earth. Contrary to all manner of accounts of the story, the sketch did not originate in 1958 during the early phase of the Mini's development—and it was not drawn on a napkin either.¹⁸ In fact, it was years later when, in order to elucidate the basic design principles, Issigonis took ink and paper to produce an illustration for a book called *The Mini Story*, published in 1964 by his friend Lawrence Pomeroy (Pomeroy 1964, Portfolio). Rather than being drawn for a client, as in Ferguson's example, the sketch was aimed at the readers of a history of the Mini. That a thick patina of legend was able to cover over the facts only goes to show the significance of the freehand sketch in the design disciplines.

¹⁷ Ferguson 1992, p. 97; Schön 1983, pp. 79–102; Ewenstein und Whyte 2007, pp. 698–701; Ewenstein und Whyte 2009. If the meeting happens over a shared lunch, then the exchange of ideas may well happen on a paper napkin (Potthast 2017, p. 60).

¹⁸ Issigonis expert Gillian Bardsley from the *British Motor Industry Heritage Trust* dates the sketch to about 1963/64 (email correspondence 4 September 2017, 25 October 2017). False accounts are to be found in, for example, Morteo 1991, p. 292; Nahum 2004, p. 50; Phaidon design classics, No. 480; Fiell and Fiell 2006, p. 284; Würth und Reiffert (Eds.) 2006, p. 76; Braun (ed.) 2014, p. 53; and even the *BMW Group Archive* dates the sketch to 1958 (URL: <https://bmw-grouparchiv.de/research/detail/index.xhtml?id=1644251>, 15 September 2017).

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