von Thienen, J.P.A., Clancey, W.J., & Meinel, C. (2021). Theoretical Foundations of Design Thinking. Part III: Robert H. McKim's Visual Thinking Theories. In C. Meinel & L. Leifer (Eds.), Design Thinking Research: Interrogating the Doing (pp. 9–72). Cham: Springer. https://doi.org/10.1007/978-3-030-62037-0

Theoretical Foundations of Design Thinking. Part III: Robert H. McKim's Visual Thinking Theories

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Abstract With his treatise "Experiences in Visual Thinking" first published in 1972, McKim delivers a milestone in the development of design thinking theory and practice. Building on creative thinking theories advanced by John E. Arnold before, McKim develops a comprehensive framework of creativity as embodied and embedded cognition. He elaborates on the role of the whole body for creative performance. In particular, he describes productive thinking as occurring during interactions with the world, where he specifically emphasizes benefits of prototyping activities. He sets forth a theory of representation systems, based on human sensory modalities (vision, hearing, touch etc.) and cognitive processing systems (such as language or mathematical processing). In each representation system, productive thinking is said to thrive on the triple activity of "perceive-think-act," which McKim elaborates for the case of visual thinking in terms of "seeing-imagining-idea sketching." To foster creative breakthroughs, a sophisticated use of multiple and varying representation systems is recommended. Overall, McKim covers in detail topics such as muscle tonus, emotion, attention, memory, perception, language, sleep and consciousness in relation to creativity. He also translates creativity theories into a creativity curriculum where opportunities for students to gain immersive experiences are considered at least as important as lecture inputs. Furthermore, McKim discusses creativity as embedded in the world and provides comprehensive recommendations for the design of places to facilitate creative work. Moreover, he coins the concept of "ambidextrous thinking," which is the immediate precursor to the concept of "design thinking" in Stanford's innovation education for engineers.

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C. Meinel, L. Leifer (eds.), *Design Thinking Research*, Understanding Innovation,
https://doi.org/10.1007/978-3-030-62037-0_2

This essay series on the theoretical foundations of design thinking takes a historical approach to clarify present-day design thinking practices. In particular, the essays explore concepts that played a crucial role in creativity education at Stanford Engineering, where the first official d.school as a university-based training facility for design thinking originated.

Today, design thinking appears as a highly practice-oriented approach to innovation at most training facilities. Notably, it emerged from rich theoretical bases—or certainly so at Stanford Engineering. One might say, when Stanford "exported design thinking culture" to many audiences around the globe, it was primarily an export of practices. The available theories were maintained mostly in-house, as "shared understandings of the locals," barely recognisable as a part of design thinking culture that could be exported as well. Yet, these theories are invaluable in helping design thinking practices become fully understandable and also applicable with greatest mindfulness and intentionality.

Against this background, it is a major purpose of this history series to make theories accessible, which informed design thinking developments at Stanford over multiple decades. The works of two Mechanical Engineering Professors at the institute, John E. Arnold and Robert H. McKim, are helpful starting points in this endeavour, because they introduced topics, theoretical frameworks and university courses with a clear legacy to present-day design thinking classes. In this sense, Bernie Roth—co-founder and Academic Director of Stanford's d.school—also recalls historical developments from his personal perspective.

> In a broad sense it started for me in August of 1962. That was when I first met John Arnold. At the time he was a professor of mechanical engineering and business at Stanford University. [...] In addition to creating and teaching project oriented courses, John consulted on problem solving and [...] organized special courses and workshops [...]. **The written materials from those workshops contain many of the concepts we now label as Design Thinking.** (Roth 2015a, p. 250f., original English manuscript, our emphasis)

One major course manuscript by John Arnold lay at the focus of part I and II in this history series. Under the headline of *Creative Engineering*, Arnold had provided sophisticated theories of creativity and innovation, as based on human needs (von Thienen et al. 2017).

Arnold had also invited world-renowned guest lecturers to his courses, such as the psychologists Joy Paul Guilford and Abraham Maslow, next to the philosopher Robert Hartman. Besides personal teaching in class, they contributed guest essays in the *Creative Engineering* course manuscript.

Robert H. McKim was John Arnold's first hire at Stanford. McKim served as a guest lecturer in the *Creative Engineering* seminar as well. His guest essay, in which he spelled out a design theory based on human needs, was the topic of part II in this history series (von Thienen et al. 2019).

Arnold's full *Creative Engineering* manuscript including all guest essays is made available with an introduction by Clancey (2016).

Beyond written materials, John Arnold and Robert McKim introduced lasting practices at Stanford Engineering. Bernie Roth continues in his personal recollections . . .

> The year I came to Stanford, John Arnold and Bob McKim started a program that they named Product Design. It was concerned with the function of products and also gave weight to its conception [. . .]. The Product Design program under Bob McKim's leadership incorporated a large dose [of] what was called need finding, which is essentially the same as what design thinkers call empathy, problem definition and point of view. There was always a big emphasis on prototyping and learning from failure in the program. (Roth 2015a, p. 251, original English manuscript)

In this chapter, part III of the history series, we discuss Robert McKim's book *Experiences in Visual Thinking* (1972), which reveals in a most lucid way how practices emerged from theory.

Experiences in Visual Thinking (EVT) is a surprising book in many regards. Upon first glance, it could be mistaken for the exercise book of a drawing class in art school. It contains many images and drawing exercises. However, upon reading, the book reveals itself as a design thinking fabric mill, in which key ideas from various origins—including especially John Arnold's *Creative Engineering* manuscript—are woven together, so as to form a coherent framework. And then, the framework is put into practice.

The overarching purpose of EVT is to train creative thinking.

> This is not a book about thinking; it is primarily a challenge to learn new thinking skills. An experiential approach is nothing less than mandatory here: no skill, whether it be in basketball, basketweaving, or thinking, can be acquired by passive reading. Skills can be acquired only by active and informed experience. (EVT, p. 4)

Thus, McKim complements his explanations of theory with dedicated practical exercises all throughout the book: the bridge between theory and practice is built right in front of the reader's eyes. Thus, in terms of educational practices, McKim endeavours a thorough shift towards immersive experiences in class. Discussions below will also show why McKim is rather sceptical of long verbal lectures in class, providing even more reasons for a pedagogical approach of immersive experiences in class, combined with only brief lecture or theory input. EVT invokes such a structure throughout—it will be familiar to present-day design thinkers, as design thinking education today follows a similar format.

Moreover, many of the exercises described by McKim will sound familiar to present-day design thinkers, such as the building of a "Spaghetti Tower," often used as an introductory task in design thinking education up to the present. This is McKim's description of the setup: "With 18 sticks of spaghetti and 24 inches of Scotch tape, construct the longest cantilever structure that you can" (EVT, p. 8). But why would it be a good idea to engage with the hands and rapidly create spaghetti tower prototypes?

In terms of special emphasis, EVT carefully explores the role of sensory processing for creative thought and communication, most prominently visual information processing. In terms of practices, this topic is omnipresent at design thinking

facilities today. Design thinkers learn to "be visual" (Plattner et al. 2009), i.e. to readily express ideas in visual forms, not only by words. Design thinkers are encouraged to build and iterate prototypes rapidly as a means for rapid learning (Osann et al. 2020), and they "prototype for empathy" (d.school 2010, p. 33). In EVT, McKim spells out the theoretical basis of such practices, why and how they aid creative performance, what to expect and what not to expect of respective skills and interventions.

Given the rich theoretical and practical suggestions of EVT, the preparation of this part III chapter in the history series took a different form than in the cases of chapters before. Along with intensive reading and personal meetings between Robert McKim and William J. Clancey, this time we also tried using the content in practice. At the HPI, Julia von Thienen hosted a one semester university class for digital engineering master students, where EVT was read and exercises were tried live. In class, the content of EVT was also discussed in light of recent research, including social science and neuroscientific perspectives. Here, we found a great alignment and continuity of observations and messages that predominated from the publication of EVT up to present-day research outcomes. Our three lines of preparation—readings, personal exchange with the author of EVT, and the staging of EVT as a university class—equally inform this review of EVT as a milestone in design thinking theory development.

1 Robert H. McKim as an Artist of Integration and Practical Experimentation

Robert H. McKim, born September 24 in 1926, is a modest, humble man, with diverse interests in art, engineering, and psychology. Still active in his early 90s, he presents as an artist, surrounded by sculptures and drawings in his backyard studio. His stories of the past combine personal inventions, 1960s experiments in "psychedelic creativity," and design pedagogy in the classroom and industry.

McKim is highly versed in various lines of theory, which he weaves together skilfully in EVT. Notably, he constructs theory in an artistic fashion, rather than as an act of bureaucratic stocktaking with ethnographic precision of who contributed which idea, when and why. McKim interprets other people's theories and re-combines them intuitively. He sometimes presents the same theoretical idea repeatedly with slight variations, akin to the way in which painters explore one and the same theme in various paintings, trying out slight variations from one painting to another.

Many impulse streams come from John Arnold, whom McKim also recognizes as a major source of inspiration.

> My greatest debt is to the late Professor John E. Arnold, who not only suggested that I develop a visual-thinking course at Stanford (a course that has been a major testing ground for this book) but also influenced me by his pioneering efforts to educate productive thinking. (EVT, p. vii)

Regular references to John Arnold in subsequent discussions underpin his important influence. At the same time, it also becomes clear how McKim actively assimilates Arnold's theoretical frameworks. They are not treated as sacrosanct final formulations, but as malleable ideas of a colleague, friend and "teammate" to elaborate and build on. A good example in this passage is a research topic attributed to Arnold. McKim says Arnold's pioneering works were aimed at educating "productive thinking." However, Arnold himself rarely ever used this term. The headline Arnold used was "creative thinking." By contrast, the concept of "productive thinking" was prominently discussed by Gestalt theorists (cf. Wertheimer 1945), who provided their own, unique treatments of creativity under this headline. Even on a terminological level, McKim condenses various traditions of thought into a novel whole.

Next to Arnold's personal works and those of Gestalt theorists, the other guest essays in *Creative Engineering* also provide major sources of inspiration for McKim. One example is the essay of Joy Paul Guilford (1959/2016), which appears as a rather disjunctive part in the original *Creative Engineering* seminar manuscript. Guilford had undertaken factor analytic studies to identify independent skills that people would need for high-level creative performance, or intellectual performance in general. He had pioneered intelligence tests to measure people's abilities on various dimensions. McKim follows up on this approach and digs deeper. Have there also been factor analytical studies on visual thinking capacities? Yes, indeed, McKim finds such pieces of theory.

> L. L. Thurstone, a pioneer in the development of psychological tests, writes: "As a result of factorial studies, during the last two decades, we no longer speak of visualizing as a single trait. We know some seven or eight primary factors that are quite distinct and which are all related to visual thinking." (EVT, p. 12)

If there are indeed independent visual thinking capacities, maybe they should also be assessed and trained independently in visual thinking education at Stanford. McKim experiments with a number of exercises akin to psychological tests (Fig. 1).

The endeavour to translate creativity theory into practical in-class exercises leads McKim also to consider Gestalt theory. One exercise he suggests is depicted in Fig. 2, showing only a couple of dots and small lines. However, for humans familiar with camels, the few dots suggest a specific "Gestalt" or resolution of the ambiguous stimulus material: There appears to be a camel.

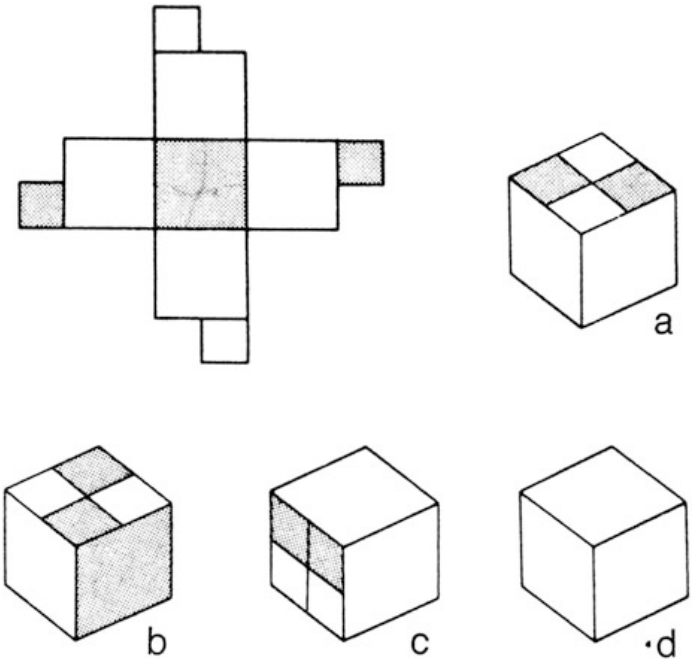

Fig. 1 Some of the exercises, which McKim invokes to assess and train visual thinking skills, build on psychometric works concerning factors of the intellect, in particular regarding visual thinking capacities. In the exercise depicted here, students should find out that the figure shown in the upper left corner can be folded into shape *a* (image from EVT, p. 15)

As spectators seeing the dots in Fig. 2, we can witness our own tendency to interpret ("view") the scene in light of prior knowledge. Easily and automatically, we use this knowledge and familiar solutions to find answers for open questions. What is this? A camel. Constructing a novel solution (figure, Gestalt) is much more effortful and time-consuming. Could the dots be showing something else? Creativity—finding non-obvious solutions—is effortful. Note how it might be helpful to team-up with people who hold different viewpoints, people who have different experiences than we do. In the extreme case, they might not even know camels. Clearly, such persons with different viewpoints and experiences could help explore alternative interpretations. Maybe they can see a different Gestalt given the same ambiguous information.

In these and other cases, McKim advances John Arnold's legacy in a self-determined, imaginative and productive way. Starting off from Arnold's intention to incorporate factor-analytic studies in creativity education for engineers, McKim uncovers further theoretical resources, such as Thurstone's psychometric works, and the treatises of Gestalt theorists. McKim turns theoretical discussions into practical exercises and uses them to reflect on creative performance in general.

Fig. 2 Some visual thinking exercises used by McKim are inspired by Gestalt psychology. An example is shown here, where observers typically detect a pattern in the dots and see a camel (image from EVT, p. 12)

2 Experiences in Visual Thinking: Training Basic Skills for Creativity

EVT comes in four major parts. First, there is a long introduction with theoretical frameworks. Then, McKim specifically trains visual thinking skills of the readers, in the order of (i) seeing, (ii) imagining and (iii) idea sketching. Sketching is trained from rough to refined, from 2D sketching to 3D model building.

Repeatedly, McKim emphasises that the overarching purpose of his book is to train creativity. Yet, many of the exercises he proposes are common-practice at art schools, to train the students' craftsmanship rather than highest levels of creativity, let alone innovation. For instance, this is one of the exercises McKim suggests for training perspective drawing:

> 1. Convergence is most easily observed in large objects (no smaller than a table). Select several large, horizontal, rectangular objects to draw in perspective.
>
> 2. To the best of your ability, make a small, freehand perspective sketch of one of the objects in the center of a sheet of newsprint.
>
> 3. Using a different-colored marker, extend all converging horizontal lines in your drawing to a vanishing point [...].
>
> 4. Repeat with several other objects. (EVT, p. 73)

How does this craftsmanship training in EVT facilitate creativity? It provides tools for creative thinkers to become most flexible and versatile in imagining novel solutions and getting them out into the world. McKim continues regarding perspective-drawing techniques:

> The visual thinker uses perspective primarily to record forms that exist only in his imagination. Consequently, in the next two exercises concentrate on seeing convergence, not in actual objects, but in rectangular solids conceived in your imagination and captured graphically. (EVT, p. 73)

Overall, a large number of training exercises in EVT appear to be directed at developing the students' technical skills, as they convey tools of the trade. How these training exercises relate to McKim's overall creativity education goals can be better understood in relation to his courses offered at Stanford Engineering. Here is an excerpt from the Stanford University Bulletin with courses and degrees 1962–1963. McKim offers the courses 112a, b and c:

> **112a. Rapid visualization**—Freehand perspective and shading techniques for rapidly visualizing design concepts. Emphasis is upon two-dimensional visual communication which is lucid and quickly executed. [. . .]
>
> **112b. Introduction to Product Design**—A study, through lecture and laboratory exercises, of the human values in product design [. . .]. Laboratory exercises consist of developing simple product concepts three-dimensionally, with rapid model making techniques. Prerequisite: 112a. [. . .]
>
> **112c. Product Design and Presentation**—A continuation of 112b, with emphasis shifted to the influence of mass production methods and materials upon design. Presentation techniques for communicating design concepts to others, especially to nondesigners, will also be considered. (Stanford University 1962, p. 114)

These descriptions sound familiar to present-day design thinkers, insofar as "rapid visualisation" is being the precursor to "rapid prototyping," which nowadays is considered a hallmark of design thinking. As Verganti et al. (2019) highlight in a discussion of design thinking approaches around the globe, the concept of design thinking has some "different interpretations" (p. 1); however a couple of characteristic elements can be identified across institutions, including an "intense use of prototyping as a rapid and effective source of communication and learning among stakeholders" (p. 2).

Notably, EVT is strongly concerned with skills needed for rapid visualisation (course 112a). It is sometimes concerned with the development of three-dimensional models (course 112b). The topic of communicating design concepts to others is only discussed in a couple of paragraphs in EVT (course 112c).

Amongst all university classes offered by McKim, courses 112a, b and c serve to establish very basic skills. Exercises related to design thinking, intended to train high levels of creativity and innovation, follow in another course series offered by McKim:

> **116a. Advanced Product Design**—Invention and development of new product concepts with emphasis upon methods for determining: unfulfilled human needs. Each design concept is developed into a working model. Prerequisites: 112a, b, c. [. . .]

> **116b. Advanced Product Design**—Continuation of 116a, with emphasis upon the influence of technology, especially "technological breakthrough," upon the formulation of new product concepts. Prerequisite: 116a. [...]
>
> **116c. Advanced Product Design**—Continuation of 116a, b, with emphasis upon developing a large, complex design to solve a "big" need, i.e., mass transportation or city planning. Prerequisite: 116b. (Stanford University 1962, p. 114)

Theoretical reflections of EVT sometimes allude to the advanced topics in McKim's courses 116a, b and c. However, these topics are not the focus of EVT training exercises. In summary, with respect to McKim's overall course content, EVT is concerned with *the basics of the basics*: predominantly with the content of course 112a. That is an important aspect in making sense of EVT as "a puzzle piece" in McKim's overall, much more comprehensive theoretical and educational works.

In this chapter, we do not endeavour to provide a complete discussion of all EVT content. Selectively, we will review theoretical frameworks discussed in EVT, which form part of the theoretical basis of design thinking practices up to the present.

The chapter provides a review of McKim's general theory of creativity (Sect. 3), his account of creativity as embodied cognition (Sect. 4), the concept of ambidextrous thinking coined by McKim (Sect. 5), the ETC process model: Express, Test, Cycle (Sect. 6) and the design of places for creative work (Sect. 7).

As in previous chapters on the theoretical background of design thinking, we will again highlight a number of central theoretical assumptions (A), definitions (D) and include some observations from a meta-perspective (M).

3 A Theory of Creativity

The topic of creativity is often mentioned in EVT. In particular, it is the overarching concept in the book's introduction. Here, McKim builds intensely on John Arnold's works in the field. In addition, McKim is very receptive towards Gestalt theory. With great interest, he acknowledges the book on visual thinking by Rudolf Arnheim (1969). Moreover, Max Wertheimer (1945) wrote about Productive Thinking, analysing acts of high-level creativity that often involve a change of viewpoint. McKim picks up on this notion. He uses both terms, "creative thinking" and "productive thinking," regularly.

According to McKim,

A1) Creative thinking requires three conditions: (1) personal challenge, (2) productive information processing and (3) flexibility.

Regarding the focus of EVT, McKim explains: "A major purpose of this book is to encourage [...] [the] third universal condition that fosters productive thinking: flexibility" (p. 2).

In this sense, McKim also emphasizes how visual capacities including drawing are important for creativity in all kinds of domains, even those where drawing is rarely taught. "Words are clearly not adequate to the thinking of a painter; as you will soon learn, words and numbers are also often inadequate to mathematical, scientific, and other non-artistic modes of [productive] thinking" (p. 3).

3.1 Personal Challenge as a Creativity Requirement

D1) Challenge means that a person is highly motivated to change a given situation; she is passionate about solving a particular problem.

As McKim puts it, "we think at our best when posed with a situation that we deeply desire to change" (p. 2). The notion of personal challenge includes some shifts away from John Arnold's earlier treatment of the topic. Arnold had highlighted "drive" as a characteristic of highly creative people, meaning a general tendency of these people to work insistently and passionately on problems. McKim rather emphasises how people differ in their emotional responses to problems. A problem that person *A* perceives as highly challenging can leave person *B* completely untouched. Facing a different problem, people's emotional reactions might be the other way around. "Challenge is a personal equation" (p. 2).

> The individual confronted with an unresolved situation that he finds fascinating and worthwhile to resolve stands a far better chance to develop his thinking abilities than the person presented with a puzzle he deems uninteresting. Of course, a meaningful challenge to one person may very well prove to be a bore to another. [. . .] Only *you* can identify the kind of challenge that will stimulate you to think deeply. (EVT, p. 25, emphasis in original)

A2) To what extent a person feels challenged by a problem is a matter of individual emotional reactions to problem situations.

Methodologically, this part of McKim's theory sheds a novel light on need finding exercises. In design thinking, addressing human needs—often interpreted as addressing user needs—is considered an essential and characteristic undertaking. McKim himself emphasized the importance of comprehensively addressing human needs in his guest essay for the *Creative Engineering* manuscript (1959/2016). Moreover, he introduced need finding exercises in Stanford engineering classes (cf. courses 116 a–c; Roth 2015a), which inform design thinking up to the present. Yet, there are some "mysteries" about need finding methods in design thinking, which can now be resolved in light of McKim's theory.

The typical procedure of need finding foresees that people working on a creative project go out into the field and meet others (potential users) for whom novel solutions might be designed. Thus, a multiplicity of "open user needs" are identified. The exact project mission is then decided by those persons who endeavour the creative project. These people are usually not the "users" themselves.

Today in design thinking, creative work is typically pursued by teams, not individuals. Most commonly, team members select the problem they will address in their creative project by voting for the one open need identified in user research that should become the team's further work objective. Thus, team members decide based on what they find personally most promising, meaningful and inspiring. This procedure is sometimes criticised as not tapping the full potential of user research, because the intuition-driven and loosely structured decision procedure does not necessarily lead teams to work on "the most crucial need" from the users' perspective. In fact, if the primary aim of the procedure was to find most important needs from the users' point of view, having users vote might indeed make more

sense than having design team members vote about the creative challenge to be tackled. By contrast, the design thinking approach used up to the present is still very well in line with McKim's theory of conditions that foster productive thinking. For the creative team to be successful, they must be personally motivated and feel challenged by a particular problem. This can be ensured best when the team decides for themselves what they find challenging and motivating.

M1) The design thinking method of having teams self-select creative projects they want to pursue—inspired, but not determined by user needs—is fully in line with McKim's theory of people needing to work on problems they experience as personally meaningful in order to be most creative.

Fortunately, of course, the goals of experiencing personal challenge and addressing key user needs are often closely aligned. It is by seeing fundamental unsatisfied needs in others, by experiencing empathy, that people gain motivation to make a change. A good example of this is provided by Bernie Roth.

> A four-person interdisciplinary team of Stanford Masters degree students were asked to create something that would change people's lives [...]. Eventually they happened upon several janitors that cleaned the building at night [...]. The students found out that the janitors had very little knowledge about financial matters and were being taken advantage of during almost every transaction [...]. The students undertook to develop and deliver Spanish language lessons about financial planning and ways to conduct financial matters [...]. One of the students was so inspired he went on to found a company, called Juntos, that allows people to use ordinary cell phones to learn about and deal with their finances. [...]
>
> I still have the original project notebook from this group. Whenever I look at the notebook I am moved to tears by the *empathy* the students felt for the janitors. It is easy to see why projects like these change students' life trajectories. (Roth 2017, p. 82f, our emphasis)

M2) Empathy allows creative teams to feel personally challenged when facing crucial rather than incidental user needs.

3.2 Productive Information Processing as a Creativity Requirement

Productive information processing is a key theme in McKim's work—up to the present day. In EVT, the topic is introduced with general reflections: "Since thinking is essentially information-processing, we cannot expect productive thinking when information is incorrect, inadequate, or tucked away in an unavailable crevice of memory" (VT p. 2).

A3) Creative thinking thrives on correct and adequate information that is readily available from memory.

Beyond such general remarks, McKim pursues quite specific teaching aims. His training programme in EVT conveys specific, basic skills for productive information processing.

Throughout the book, McKim discusses the dimension of "concrete" versus "abstract" information processing. He highlights how attending to concrete details of sensations allows us to gather comprehensive information beyond stereotypes. It enables us to note details "outside the box" of prior concepts and expectations. By contrast, abstract thinking can crystallise the gist of a concept or viewpoint. Yet, when it lacks consciously made choices and flexibility, abstract conceptualizations are very often stereotypes that drive "thinking inside the box."

A4) Concrete thinking is non-stereotypical; it drives thinking "outside of the box."

A5) Abstract thinking can crystallize the gist of a concept, but it can also advance stereotypical thinking "inside the box."

McKim trained concrete information processing with regard to multiple sensory systems in his overall educational programme. At Stanford, he built the Imaginarium, where students practiced devoting attention to concrete perceptual experiences—across all sense channels, not only in the visual domain:

> When was the last time you gave all of your attention to the sensory experience of smelling an apple? [. . .] After several minutes in the Engineering Department Imaginarium, you could be doing just that [. . .]. The Imaginarium is a red, 16-foot geodesic dome, designed and outfitted by Prof. Robert McKim of the Mechanical Engineering (ME) Department here. [. . .] Created in 1972 [. . .], the Imaginarium is used in ME 101, "Visual Thinking," [. . .]. Slides and films are projected onto the white interior of the dome. Music, thunderstorm noises and numerous other auditory and touch stimuli are used. (Wentworth, Stanford Daily, 1978, p. 2)

In contrast to this plurality of sense-channels addressed in the Imaginarium, EVT is primarily concerned with visual thinking. The detailed treatment of visual skills in EVT can be understood as a prototypical training programme; the use of other sense channels could be trained in similarly refined ways to foster creative thinking. Overall, trainings progress from mindfulness of immediate sensations to similarly rich imaginations. Students learn to include all their senses when imagining something new.

> At one point participants [in the Imaginarium] imagine they're in an apple orchard. We inject the smell of apples through the air conditioning system [. . .] McKim said. (Wentworth, Stanford Daily, 1978, p. 2)

All in all, mindfulness of sensations emerges as a key concept in this training endeavour. One major reason why mindfulness is considered serviceable for creativity is because it facilitates concrete thinking outside the box.

A6) Mindfulness of immediate sensations facilitates concrete thinking "outside the box" and thus also facilitates creative thinking.

To diagnose his students' ability for concrete information processing, McKim invokes drawing exercises in EVT. Depending on outcomes, the diagnosis might be that a student is strongly inclined towards abstract, stereotyped thinking. The same drawing exercise, conducted repeatedly, could then serve to train the student's skills

in concrete information processing:

> Taught always to name what they see, many students learn to label the visual stimulus too quickly, before they see it fully. For example, the word-dependent individual rarely sees trees in all their many shades of green and trunk-bark-limb-twig-leaf complexity. Instead, he sees trees as abstract visual concepts, vague green blobs on a stick. [...] Asked to draw a tree, the individual whose visual ability has atrophied can only draw a primitive green lollipop. (EVT, p. 24)

A7) Drawing is a means to test and train people's concrete information processing ability (in the sample domain of visual thinking).

The importance of "productive thinking" and "mindfulness" in McKim's overall framework of thought is further evidenced by his extensive and repeated mentioning of the topics in recent conversations with William J. Clancey.[1]

On January 31, 2018, McKim laid out to Clancey that "not all thinking is good thinking." For example, "going in circles" is not good. Losing concentration or attention is not good. Allowing the "chatter" in your mind (e.g., about what others think) is not good—it is "junk thinking." For example, McKim explained how such chatter would make it impossible to produce the rapid drawings he created. Moreover, allowing your biases to confine your ideas is not good. He referred to the section on "Relaxed Attention" in EVT as to characterize the opposite of chatter. Thus, chatter or unproductive junk thinking can be contrasted to mindfulness, flow and relaxed attention.

On January 29, 2019, McKim emphasized to Clancey that "we are always thinking." However, some thinking is just "bad thinking." Examples include thoughts that move in circles when worrying about something (obviously a prototypical instance of the mind's "chatter"). Bad thinking also occurs when ideas are based on clichés and stereotypes. All this bad thinking is not productive. By contrast, productive thinking is both creative and ethical/moral. Creative thinking breaks new ground, it is not based on clichés and stereotypes. Yet, creative thinking can be unethical or "morally blank." In that case, McKim does not consider it to be "productive." Thus, here he adds a distinction between creative versus productive thinking that is not specifically discussed in EVT. Yet, the importance of moral designs was already a major topic in his *Creative Engineering* guest essay (McKim 1959/2016; von Thienen et al. 2019).

On December 9, 2019, McKim expressed to Clancey and Jan Auernhammer that "it's most important not to allow the mind to wander off. Watch your mind, don't let it kick you around. Notice when the mind is unproductive: Going in circles, never ending, never producing anything. Silence that part of your mind."

These recent explanations are in strong continuity with McKim's earlier works, including EVT. Here, he lays out his rather broad conceptual understanding of "thinking," which then includes both productive as well as less productive mental activities.

[1]The following recollections are based on extensive notes taken by William J. Clancey during seven personal conversations with Robert McKim during 2016–2019.

> Irrational or sane, habit-ridden or brilliantly incisive, logical or illogical, awake or dreaming, we think with our entire being almost all the time. By this broad definition, most thinking is not "productive." We need not assume, as some writers do, that mental activity which merits being called "thinking" is necessarily good thinking. Indeed, most thinking that is eventually productive is preceded by frustrating, cycling, abortive, ill-informed, illogical, habit-plagued thinking that produces (at the time) very little of value. (EVT, p. 2)

McKim also trains readers to monitor their imaginative activities. When thought cycles become apparent, readers should learn to silence these imaginative impulses and instead direct their thoughts into more productive directions:

> The scenarios of many daydreams are enormously predictable; they are "the reverse of a present frustration," [...]. "If broke, we fantasy winning the sweepstakes. If jilted, we wallow in fantasied revenge." The repetitiveness of these compensatory daydreams testifies to their inability to solve problems. While the active visual thinker directs his fantasies towards expression in reality, the compensatory daydreamer escapes from reality into fantasy, where he cycles passively and endlessly.
>
> Not all daydreaming falls under the heading of escape-to-fantasy, however. Many visual thinkers use a form of daydreaming to think productively. (EVT, p. 95)

Similarly, McKim submits:

> Look inward, become aware of your imagination, and learn to control it productively. If you are aware of your inner imagery but are unable to control it (if you are prone to drift in cyclic and unproductive daydreams, for example), then learn to extend your awareness into other modes of imagery and, again, learn to direct your imagination toward productive ends. (EVT, p. 83)

EVT also spells out a theory of attention (Sect. 4.2), where McKim uses the term "passive attention" to describe an individual whose thought content is driven or even "dictated" by the environment. This contrasts to a productive thinker, who maintains control over his own thinking by means of metacognitive oversight. The productive thinker devotes "voluntary attention."

Given the strong continuity in theorising, even recent explanations of McKim can help to obtain further terminological clarity.

D2) Productive thinking advances creative (novel and effective) solutions that are ethical.

D3) Chatter is thinking that yields no constructive ideas, such as cyclic thoughts about the opinions of others or rumination regarding personal worries.

A8) The thought processes of a person can be non-productive in three major was: (1) when the person does not strive for ethical, creative solutions; (2) when she becomes distracted by chatter or a loss of attention; (3) when the person generally lacks necessary skills to advance ethical, creative solutions.

A9) The process of productive thinking, prior to the achievement of final solutions, is characterized by long phases of the mind staying intentionally "on topic," and by mindfulness for concrete experiences beyond clichés or stereotypes.

The concern of McKim for mindfulness was later continued by Rolf Faste at Stanford Engineering. Faste also authored a book manuscript under the headline of

"Zengeneering."[2] It explores in detail the role of "Zen" mindfulness for creative and worthwhile engineering.

More recently, the design thinking research group of Manish Saggar (2017) has continued this tradition of theorizing. They have investigated the difference between unproductive going-in-circles ("rumination") versus productive design reflections in fMRI scans.

3.3 Flexibility as a Creativity Requirement

A major purpose of McKim's book EVT is to help people become more flexible in their thinking. This is to be achieved by practising different thinking strategies, where each approach renders some actions easy, but it may be hampering with regard to other actions. In his explanation of the topic, McKim borrows an analogy from David Straus: The strategy repertoire of a creative thinker is like the toolbox of a carpenter. What a poor carpenter the person would be who only knew how to handle a hammer. A hammer is very practical for some purposes. Yet, the carpenter will need different tools for other purposes. Similarly, an engineer who always invokes the strategy of analytical thinking could solve some problems very well, but could barely handle others. To be proficient in creative problem solving without being limited to very specific kinds of problems, the creative thinker needs to be proficient in a large strategy repertoire, like the carpenter who needs to be proficient with a diversified tool kit:

> Once he [the carpenter] has mastered the use of a tool, it becomes almost an extension of his hand. [...] His knowledge and skill with his tools ... determines a substantial part of his overall ability as a carpenter. (David Straus, quoted in EVT, p. 161)

McKim emphasizes the importance of exercise and practical skill for the development of flexibility. When a person working on a creative project is able to see different meta-options she has—different tools she could use—this is already good. Yet, much exercise may be needed before she is actually able to pursue each meta-option in practice—before she masters the various tools so well that they basically extend her physical abilities.

D4) Flexibility is a superordinate ability to choose between various, complementary strategies of thought and action, which the person is able to pursue proficiently.

According to McKim's summary, EVT trains 30 overall strategies, each based on numerous methods and exercises. His list gives a good overview of the book's content: Relax, devote attention, experiment with drawing materials, purge, think directly in 3-D, re-centre (which might be called "change point of view" nowadays), pattern-seek, define, imagine, project, recall, seek an analogy, dream or daydream,

[2] http://www.fastefoundation.org/about/zengineering.php

foresee, subjectify, analyse, re-proportion, modify, clarify, rotate, manipulate, look inside, generate alternatives, test, cycle, repeat, change idiom, incubate, intuit, stop thinking.

Of course, McKim is not the first person to endeavour such strategy compilations. Amongst the many authors concerned with creativity, Alex F. Osborn prominently compiled somewhat similar lists, as presented and discussed in Arnold's *Creative Engineering*. The comparison is illuminating. Osborn's strategy list comprises the following approaches: "Put to other uses? [. . .] Adapt? [. . .] Modify? [. . .] Minify? [. . .] Substitute? [. . .] Rearrange? [. . .] Reverse? [. . .] Combine?" (Osborn, cited in Arnold, 1959/2016, p. 98). This compilation is concerned with how to re-think things, how to generate ideas for new things based on what is already given. By comparison, McKim adds numerous meta-strategies for creative work, such as relaxation, devoting attention, daydreaming, using intuition or stopping to think.

Generally, the topic of flexibility was already emphasised in Arnold's (1959/2016) *Creative Engineering*. McKim elaborates the subject and provides a novel structure. Arnold began his treatment of the topic with a discussion of "flexibility" as a key construct in the psychometric works of Joy Paul Guilford. There, a person's flexibility was rather narrowly assessed by asking people to name as many alternative uses for existing objects as the person could think of. To Arnold, flexibility is important in many more ways. He generally understands it as the ability of a person to consider meta-options, including different potential points of views, different work approaches, different solutions etc. (cf. von Thienen et al. 2017). Arnold names various examples of how creative thinkers can be flexible, but he does not provide a system. McKim adds a huge number of further examples beyond those discussed by Arnold in *Creative Engineering* and systematises them into three different categories.

A10) Thinking can be flexible in three major ways: (1) in levels of thinking: from deliberate/conscious to automatic/non-conscious, (2) in thinking operations, such as analysis vs. synthesis or diverging vs. converging, and (3) in the use of different representation systems for information: verbal, mathematical, visual, tactile, acoustic, emotional etc.

Regarding the first category, McKim explains:

> Flexibility in levels of thinking is demonstrated by thinkers who know that it is sometimes advisable to stop thinking consciously about a problem, to relax, to take a walk, to sleep on it—in short, to allow thinking to proceed unconsciously. Productive thinkers are also alert to recognise ideas that emerge from unconscious levels. (EVT, p. 2)

Methods that McKim trains on this behalf include relaxation exercises borrowed from psychotherapy and meditation, stretching and the writing of a dream diary, amongst others. (For present-day research findings concerning this topic, cf. the chapter "Neurodesign Live", in this book, specifically the neurodesign lecture input of Mathias Benedek.)

The second type of flexibility required for creativity concerns thinking operations:

> Most thinkers are disposed to use a limited set of favorite thinking operations. The logical thinker likes to operate his thinking by rules of logic, step-by-step, in a single direction. The intuitive thinker, by contrast, appears to take "mental leaps," often in surprising directions. While acknowledging a genetic influence in this personal bias toward certain mental operations, we can also see that education that rewards certain thinking operations, ignores others, and even penalizes as a few, is also bias inducing. (EVT, p. 2f.)

With regard to these biases, EVT intends to provide an antidote by training thinking operations often neglected in formal education. One can easily see how strategies such as relax, re-centre, imagine, daydream, incubate, intuit or stop thinking from McKim's list are rarely promoted elsewhere at universities, especially at engineering faculties. In the end, flexibility in the use of strategies or thinking operations is desired. "An important purpose of this book is to encourage the reader to enlarge his working repertoire of thinking operations and to learn the value of moving from one operation to another" (p. 3).

Regarding flexibility in representation systems, McKim uses changing terminology. Next to writing about representations in different systems, he also uses the terms "vehicles of thought" or "languages of thought." To aid clarity, we will only use the phrase "representation system" henceforth. In this respect, once again, McKim seeks to promote flexibility. Further details about McKim's theory of representation systems and his ideas concerning their flexible usage are discussed in Sect. 4.4.

4 Creativity as Embodied Cognition

Beyond McKim's description of three basic requirements for creativity—personal challenge, productive information processing and flexibility—McKim also reflects on the physiological underpinnings of the phenomenon. These reflections of McKim are specifically meaningful for recent developments in the field of design thinking, which take place under the headline of "neurodesign." Here, the bodily basis of design thinking is being explored (Auernhammer et al. 2021; von Thienen et al. 2021).

In present-day laboratory studies of creativity, very often the brain lies at the centre of physiological scrutiny. While participants work on creativity tasks, brain activities are monitored by means of EEG-recordings, fMRI or fNIRS. From McKim's perspective, the brain is just one part among many others in the human body, which matters for creative performance. His stance would nowadays be described under the headline of "embodied cognition." In this domain, present-day scholars discuss how the entire body of an animal shapes its cognitive processes. This is also a key topic for McKim across his whole book. "The entire nervous system (not just the brain) is involved in thinking" (EVT, p. 2). "We think with our

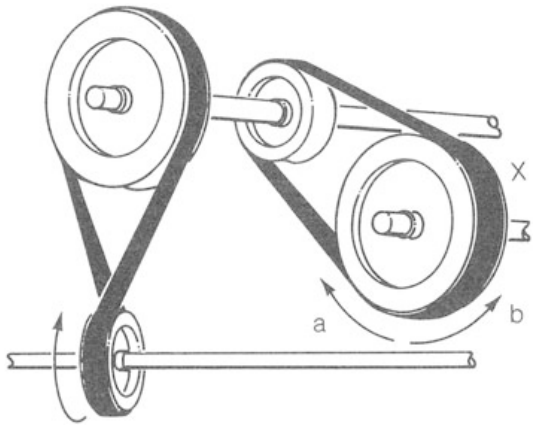

Fig. 3 One exercise in visual thinking asks readers to determine the direction in which one pulley will turn given interventions on another pulley (image from EVT, p. 16)

entire being" (ibid.). "Psychic (mental) functions cannot be readily separated from somatic (bodily) ones" (p. 1).

A11) Creative performance is a matter of the whole body, not just the brain.

EVT includes ample exercises for people to train their bodily skills and it provides encouragement for readers to engage in physical activities—all in the service of creativity.

A12) Bodily skills (such as accurate perception or drawing), physical activities (such as walking, relaxing or 3d-model building) and physical environments (including materials that promote different kinds of engagement with the environment) are essential determinants of people's creative capacity and creative performance.

All upcoming sections will elaborate this perspective. Whatever topic McKim turns to in EVT, the role of the whole body for creative performance is always highlighted.

Even when a problem is to be solved mentally (i.e. "in the brain"), McKim draws attention to the role of our body morphology—beyond the brain—for the information processing that takes place. In one example (Fig. 3), McKim depicts two pulleys. He asks:

> Which way (a or b) will pulley 'X' turn?
>
> Did you trace the motions of the pulleys with your finger, or feel some sort of inner muscular involvement, as you came to the correct conclusion that pulley "X" goes in direction b? (EVT, p. 16)

As humans, many of us solve this puzzle by mentally simulating operations with fingers, hands and arms. These operations are based on our human body-morphology. If we had different appendages for the handling of artefacts—if we had trunks like elephants or bills like birds instead of hands—our mental operations would be different in order to solve the problem.

4.1 A Theory of Relaxed Attention

In considerable depth, McKim especially elaborates how muscle tonus (relaxation) impacts emotions, attention processes and productive versus non-productive information processing. McKim holds that:

A13) Relaxed attention is most favourable for creative, productive thinking.

> Relaxation is important to thinking generally, because we think with our whole being, our body as well as our brain [. . .]: uptight body, uptight thoughts. Be reminded, however, that the totally relaxed individual cannot think at all [. . .]. [S]ome muscular tension is needed to generate and attend mental processes. Some tension, but not too much: relaxed attention. (EVT, p. 33)

In his overarching theory of creativity, McKim holds that it is important to develop flexibility in one's levels of thinking: from controlled, conscious, deliberate to automatic, non-conscious, non-deliberative cognitive processing. For highest levels of creative performance, creators need to be ready to harness both kinds of information processing. Again, he highlights that these are whole-body engagements, not just brain-specific processes. A typical example of non-deliberative processing occurs during sleep.

A14) To facilitate creative breakthroughs, the creative individual needs to be ready to process information in varying body-states, from energetic and controlled work on a task to automatic, non-conscious information processing during phases of relaxation with attention off-task (e. g., taking a shower, going for a walk, sleeping).

> **The paradox of ho-hum and aha!**
>
> Relaxation involves loosening up, letting go, and finally—ho-hum—going to sleep. Attention involves focusing energy, finding excitement in discovery—aha!—and being very much awake. Ho-hum and aha!—what can these seemingly opposed modes of consciousness have in common? [. . .] After a period of relaxed incubation, which can take place in the shower or on a peaceful walk as well as sleep, attention is not uncommonly riveted by the "aha!" of sudden discovery. [. . .] While the subconscious incubation requires relaxation, a sudden flash of insight requires attention or is lost. (EVT, p. 33)

Here, McKim expresses another claim regarding work phases where the creator does not think about his or her creative project in consciously controlled ways.

A15) When creators work on long, complex problems, breaks or resting periods most effectively increase chances of breakthrough insights when relaxation is achieved.

From the perspective of present-day (neuro-) design thinking research, also another aspect is notable in McKim's discussion: Two out of three examples he gives for situations that facilitate automatic, non-conscious problem processing involve relaxed, bilateral, fluid motion: going for a walk and taking a shower. Only the example of sleep describes a rather motion-less state. Notably, McKim's examples are highly consistent with more recent research findings, which indicate a strong facilitating effect of relaxed, bilateral, fluid motion on creative thinking (von Thienen 2018).

McKim is furthermore concerned with interrelations of body-states and emotions. He holds that:

A16) There is a bi-directional causality between body-tension and fear: fear causes tension; body-relaxation reduces fear.

> By far the most fundamental cause of hypertension is fear. The fearful or insecure person tenses his body because he believes that he will soon face a real or imagined attack or catastrophe. At work, he overreacts and burns energy needlessly, or does not act at all—in each instance, to avoid failure. At home in bed, he fusses and worries; his body tense, he cannot go to sleep.
>
> Unable to relax, the fearful individual also finds it difficult to maintain attention. Every distraction is interpreted as a potential threat or an opportunity for relief. Easily diverted, he becomes prone to the conflicting mental agenda and immobile tension that characterize the indecisive. (EVT, p. 34)

McKim notes that many people try to counter excessive tension with alcohol or other drugs. "Indeed, so prevalent is tension that large industries cater to letting go: alcohol, drugs" (p. 34). While McKim does not seem to believe much in relieving effects of alcohol or other drugs, he is fully convinced of the positive impact of bodily relaxation exercises: "Physical-relaxation techniques provide an excellent way to break the cycle of fear, worry, and tension" (p. 34).

In terms of McKim's more recently used terminology, one can say that

A17) Excessive body-tension and fear provide a physiological basis of "chatter," "junk-thinking," or altogether unproductive thinking.

To counter unproductive thinking, McKim suggests bodily exercises.

> Holding the heavy human head over a desk for long periods while looking rigidly straight ahead at paperwork is a comparatively recent behavior that places an extremely unnatural demand on neck and shoulder muscles. These areas should be relaxed periodically, and always just before intensive visual/mental activity. (EVT, p. 35)

Ever since this theoretical acknowledgement of body states impacting creative performance, physical activity has been a typical element in design thinking warm-ups prior to creative work proper. Bernie Roth recalls how such physical activities were initially considered awkward in Stanford's School of Engineering, but gradually became accepted.

> There are movement activities that directly use the mind-body connection to stimulate learning and creativity. In the Design Division, we have been teaching these activities for a long time. Originally, these were considered somewhat New Agey. [. . .] The president's office could not see any justification for an engineering design class being in the women's gym for warm-up exercises. Fortunately, those days are long past. (Roth 2015b, p. 179f.)

M3) Body motion has been introduced as a typical element of design thinking warm-ups to foster a flexible muscle tonus in the whole body, and to facilitate relaxed attention in subsequent creative work.

The ability to achieve body states at highest levels of relaxation is considered favourable in several regards.

> Deep muscle relaxation prepares the individual to sleep—perchance to dream—or, if mental alertness is retained, to imagine more vivid and spontaneous visual fantasies than can usually be obtained with normal muscle tonus [. . .]. (EVT, p. 36)

A18) Deep muscle relaxation leads to sleep and thus increases chances of dreaming, when alertness is not maintained.

A19) Deep muscle relaxation leads to enhanced (more spontaneous and more detailed) imagination, when alertness is maintained.

Yet, again, McKim emphasizes the importance of flexibility, also with regard to muscle tonus. Deep relaxation is one extreme that creative individuals should be capable of, but abilities of tensing the body are as important. Body tenseness is understood as a physiological prerequisite for focused attention. As McKim explains: "Devotion of attention is the focusing of energy. The vehicle for transmitting human energy is muscular tension" (EVT, p. 36).

A20) Muscular tension is a physiological basis of building up and focusing attention.

> By relaxation, you let go inappropriate muscular tensions that divert energy from what you are doing; by attention, you direct and devote your energy, freely and dynamically, to discovering more and more about a single object, idea, or activity that interests you. Old habits, however, may initially make the task of maintaining the state of relaxed attention difficult. Excessive tension reappears; the mind wanders. (EVT, p. 38)

Against this background, McKim provides exercises to help readers "clear the ground of consciousness so that the physical and mental and emotional awareness inherent in relaxed attention can be maintained for longer periods of time" (p. 38).

4.2 A Theory of Attention

The ability of people to persist with on-task attention is considered a prerequisite by McKim for productive thinking (cf. Sect. 3.2). Here as much as in other cases, he endeavours to provide (neuro-)psychological accounts of cognitive processing in general, and creative thinking in particular. Today, the bio-psychological basis of creativity is a core topic in the emerging field of neurodesign (Auernhammer et al. 2021; von Thienen et al. 2021); McKim has laid important groundwork in this field.

In detail, McKim spells out a theory of attention, closely intertwined with his discussion of body-tonus.

A21) Different states of attention to distinguish include: forced attention, immersed attention, passive attention, preattention and voluntary attention.

D5) Forced attention occurs when the person is instructed to pay attention to a task, or the person instructs herself to attend a task, which she does not find interesting per se.

A22) Forced attention can only be maintained for short periods of time; it is effortful to maintain and does not allow the individual to tap her full creative potential.

> Externally or internally demanded, *forced attention* usually occurs for brief moments only, and must continually be reinforced.
>
> Paying attention because you should or ought to is clearly less pleasant, and less effective, than devoting attention because you want to. (EVT, p. 36)

Here, McKim's theory of attention underpins his theory of creativity, where he introduces "personal challenge" as a pre-requisite for high levels of creative performance (Sect. 3.1).

A23) When a task does not interest the person, she does not feel personally challenged and can devote forced attention only; under such circumstances, the person cannot unfold her full creative potential.

The situation is very different when a task does interest the person.

D6) Immersed attention occurs when the individual is highly interested in a task and gets so absorbed in the activity that she loses self-conscious reflections on a meta-level regarding the situation.

A24) Immersed attention is experienced as pleasurable and attention is not easily diverted away from the task; it can be observed regularly in playing children.

> The individual who attends because he wants to is not easily diverted. *Immersed attention* is natural absorption in developing an idea, contemplating an object, or enjoying an event. Watch a child pleasurably engrossed in stacking blocks to obtain a clear image of *immersed attention*. (EVT, p. 36)

Very different from immersed attention, is a state that McKim addresses as "passive attention."

D7) An individual pays passive attention when she only reacts to whatever stimuli appear in her environment.

A25) With passive attention, the person tends to pursue each task only for a limited amount of time, and tasks are not consciously self-determined, because attention wonders from one objective to another cued by the environment.

> Immersed attention should not be confused [. . .] with *passive attention*, which is being easily absorbed, willy-nilly, in whatever comes. The passively attentive child who "seems to belong less to himself than to every object which happens to catch his notice" presents a formidable challenge to his teacher. (EVT, p. 36)

In light of McKim's more recent terminology, passive attention can be related to the concept of "unproductive junk thinking." Here the person occupies herself with topics that draw attention away from a project, which the person could otherwise pursue productively.

The next concept of attention to distinguish is "preattention."

D8) Preattention means that a person pursues a routine task mostly by means of automatic processing, with relatively little conscious reflection required.

A26) Complicated, novel tasks cannot be solved by means of preattention; they require full attention.

> *Preattention* is another natural form of attention. Absorbed in thought, for example, you suddenly realize that you have somehow negotiated your automobile through miles of turns and traffic without conscious awareness: you have been preattending the driving task. Preattention is comparable to an automatic pilot that attends routine events but cannot cope with the unusual. Should a highway emergency occur while you are preattending [. . .], you must come to full attention to cope with it. (EVT, p. 37)

Then, by contrast, the most important form of attention McKim distinguishes in the context of creativity is "voluntary attention."

D9) Voluntary attention occurs when the person immerses in a task only to such a degree that self-conscious reflections on a meta-level are maintained, which allow the individual to change foci of attention wilfully.

A27) Voluntary attention is best suited for visual thinking activities.

> Of the kinds of attention discussed so far, immersed attention would seem at first best suited to visual thinking. What could be better than being able to "lose oneself," to become wholly immersed in what one is doing? Emphatically better is a quality of attention in which sense of self is not lost and consciousness is not taken over entirely by what one is attending. I will call this kind of attention *voluntary attention*. The individual who attends voluntarily is able to change the focus of his attention quickly, at will. To do this, his consciousness cannot be wholly immersed; he must be sufficiently self-aware to be able to decide. (EVT, p. 37)

Here, McKim adds discussions about attention mechanisms to an account of flexibility advanced by Arnold before, where he had discussed one aspect of flexibility from a perspective of "personality."

> Flexibility [. . .] is also the ability, that can be consciously developed, that allows you to be both an observer and a participator at the same time or in alternation. It is most desirable to have this duality of personality be constant in time if the observer half is not acting as a judge or evaluator [. . .]. Perhaps the alternating roles would be the safest at first. This would allow you to step back every so often and review what you have done to date and to reconnoiter and determine the best path to continue along. (Arnold 1959/2016, p. 86)

McKim explores how persons can achieve the kind of "flexibility in personality" that Arnold had described in highly creative persons. Like Arnold, McKim emphasizes the possibility of enhancing flexibility by means of practice. In McKim's framework, this informs his statements about attention.

A28) Voluntary attention can be trained.

Moreover, McKim spells out conditions under which voluntary attention develops, or can be maintained. Thus, students can train to develop and maintain voluntary attention, by seeking its favourable conditions.

A29) Voluntary attention (i) can only be devoted to one topic at a time, (ii) requires that you take interest in the topic and (iii) can be sustained only through ongoing, dynamic processing of the topic.

> Like the art of relaxation, skill in voluntary attention can be learned. The first principle to learn is that you can fully attend only one thing, or related group of things, at a time. [. . .] [Then comes] the second principle of voluntary attention: find interest in what you are attending, or your attention will wonder, become divided, or have to be forced. [. . .] [T]he third principle of voluntary attention is that attention is dynamic. Whenever mind and eye become immobile, attention diminishes and vision blurs. (EVT, p. 37)

Here we can witness the origin of the design thinking motto "stay focused on topic," sometimes followed by the explanation "one conversation at a time." This motto grounds in insights regarding human physiology. Our mind (in more recent

terminology: the working memory) is not made to pursue different unrelated topics or tasks consciously at the same time:

> You can fully attend only one thing, or related group of things, at a time. True, you can preattend one thing (of a routine nature) and attend another. But try to attend fully two unrelated conversations at a time, and you will find that you can do so only by alternating your attention between the two. You will also find that your attention naturally favors the conversation that most interests you [. . .]. (EVT, p. 37)

A30) Splitting up attention across several tasks or topics at a time decreases performance on each single task and hampers productive thinking altogether.

Thus, creative persons should seek to devote their full attention to one important matter at a time, instead of trying to split up attention. This is the "one topic," the "one conversation" for design thinkers to focus on, where immersive experiences are to be sought. Notably, this does not mean at all that design thinkers should stay fixed on a particular topic from the beginning of a creative project to its end. This would be absolutely disastrous for creativity, as flexibility in one's focus of attention and openness to seemingly irrelevant information have been found by research to be essential for high levels of creative performance (von Thienen 2019). Yet, the motto "stay focused on topic," building on McKim's theory of attention, also implies something very different.

M4) The design thinking motto "stay focused on topic" means in McKim's terms "devote voluntary attention": Seek immersion in one objective at a time, maintain meta-cognitive oversight, be ready to flexibly shift your focus of attention deliberately (not in purely passive reactions to ever-changing environmental stimuli).

Finally, McKim distinguishes between "internally" versus "externally" directed attention.

Internally directed attention allows the person to access her own "inner" imagery and to use it for productive purposes. "Look inward, become aware of your imagination" (EVT, p. 83). Internally directed attention can also serve to explore bodily sensations. "Close your eyes and sit quietly for several minutes. Allow your attention to systematically explore the muscle sensations of your body" (p. 35).

This contrasts to externally directed attention, where the person is mindful of her surroundings, including objects in the environment. An example discussed above is the seeing of a tree. In the respective exercise, McKim instructs readers to look closely and pay attention to the "many shades of green and trunk-bark-limb-twig-leaf complexity" (p. 24).

Both internally and externally directed attention are highly important to McKim. He trains them regularly. In particular, the chapter "seeing" includes many tasks where readers practice externally directed attention. In the chapter "imagining," multiple exercises call for internally directed attention.

D10) With internally directed attention the person focusses on mental imagery or on proprioception.

D11) With externally directed attention the person focusses on her environment.

Indeed, the topic is so important to McKim that he even designs environments specifically to facilitate internally versus externally directed attention. Notably, from one purpose to the other, different environments can be required. Internally directed attention benefits from quiet, secluded environments: "Inner stimuli, often fragile, are easier to attend in an environment in which external stimuli (such as distracting noises or interruptions) are absent" (EVT, p. 85). By contrast, externally directed attention thrives from stimuli in the environment that elicit interest, or materials that facilitate active engagement with the surroundings (see Sects. 7.1 and 7.2).

M5) Environments for creative work should facilitate both internally versus externally directed attention. Typically, different kinds of environment are needed for the two ends.

4.3 A Theory of Memory

Next to his theory of attention, McKim also spells out a theory of memory. Once again, he provides an embodied cognition account. According to this view, what we remember is a matter of our whole body. In particular, muscle tonus and relaxation play a key role in McKim's memory conception.

The topic of memory is important indeed in the context of creativity. Already historically old creativity theories acknowledged the fact that novel ideas are in some way informed by what the person knew before. In one traditional theory, creative ideas are defined as a novel re-combination of old ideas. John Arnold had also included this aspect in his definition of creative thinking.

> The creative process is primarily a mental process whereby one combines and recombines **past experience**, possibly with some distortion, in such a fashion that the new combination, pattern, or configuration better solves some need of mankind. (Arnold 1959/2016, p. 66, our emphasis)

When past experience is essential to the creative thinking process, then—in terms of (bio-)psychological theory—memory functions are involved. From present-day perspectives, such an account has lost nothing of its topicality. Research finds similar brain areas recruited when people remember the past or engage in creative thinking (Beaty et al. 2018; see also the input of Mathias Benedek in the chapter "Neurodesign Live").

M6) McKim moves beyond a psychological theory of creativity; by discussing the role of the whole body in relation to attention, memory and creative thinking he provides a bio-psychological theory of creativity.

With regard to memory, McKim highlights its essential importance for creative performance: "We cannot expect productive thinking when information is [...] tucked away in an unavailable crevice of memory" (VT p. 2).

A31) Abilities of memory retrieval partially determine people's creative capacities.

In the section on externalized thinking (Sect. 7.1) and prototyping (Sect. 7.2) McKim lays out how people can use material culture in order to extend their memory. For instance: "Idea sketches are [. . .] a kind of visible graphic memory" (p. 121). He also points out how material culture extends our memory functions, so that we can conduct mental operations that would be impossible without material aids.

> Drawing provides a function that memory cannot: the most brilliant imager cannot compare a number of images, side by side in memory, as one can compare a wall of tacked-up idea sketches. (EVT, p. 10)

A32) Material culture permits mental operations that human memory alone (unaided by material culture) would not support.

Beyond the use of material culture, McKim also addresses perception skills and practices as highly relevant for memory performance. Schooling perception ("mindfulness") is a key approach he takes in order to help people improve their memory retrieval capacities.

> **visual memory**
>
> Ability to retain visual imagery is difficult to measure. One can never be sure that a low test score is the result of poor memory; it could as well be the result of inaccurate perception. Indeed, **vigorous perception and faithful remembering are closely allied**. The more actively you perceive [. . .] designs, the more likely you will be able to reproduce them from memory. (EVT, p. 14, our emphasis)

McKim invites readers to try the following exercises.

> Close your eyes and recall an apple [. . .]. After a minute or so, open your eyes and ask yourself: "Did I see a colored apple? Was it a specific apple? What was the apple resting on?"
>
> Most people, when attempting to recall an apple, either experience blank or inobedient imagery or a stereotyped red apple that floats in space. (EVT, p. 91)

Based on his memory theory, McKim asks readers to reflect on their conscious experiences when eating apples. He notes how conscious experiences depend on people's focus of attention. Likely, a lack of voluntary attention devoted to apples while eating them, and correspondingly a lack of comprehensive and accurate perception, explains a bad performance in the "remember-an-apple-test."

> When you last munched an apple, for example, were you fully conscious of its nuances of color, flavor, scent, coolness, crispness, and texture? Likely not. More probably, you were talking to someone or thinking of something else. If my assumption is correct, your image of an apple in the previous exercise was as lacking in sensory detail as your usual conscious experience of apples. (EVT, p. 91)

A33) Capacities of memory retrieval depend on previous conscious experiences; only what is consciously experienced first can later be easily retrieved from memory.

A34) Paying voluntary attention to an object or situation, and exploring it actively across multiple sensory modalities (mindfulness), improves the recall of multimodal details concerning the object or situation from memory later on.

While keen visual perception is relatively easy to train, McKim emphasizes that people often find it much harder to be mindful of other sensory experiences. Many of them are commonly processed non-consciously. Cultural blocks antagonize a balanced conscious exploration of all sensory modalities.

> Nonvisual sensory modes are particularly repressed because they are especially related to feelings of pleasure, disgust, and pain. The olfactory pleasure of perfume (and disgust at the smell of spoiled food), [. . .] the kinesthetic pleasure of dancing (and ache of sore muscles), the auditory pleasure of music (and nerve-jangling noise of the city): these feelings that accompany the nonvisual senses are particularly intense. Because we naturally avoid pain and, obeying cultural strictures, also commonly avoid pleasure, we tend to repress much sensory experience. Sensory experience that is not actively and consciously assimilated is also not readily remembered. (EVT, p. 92)

To help people recall sensory experiences that were not actively and consciously assimilated at the time of the initial experience, McKim suggests a method, which he calls *relaxed multimodal retrieval*.

> Now consider the rationale for a retrieval method that will enable you to recall more vivid and complete memory images. I will call this method "relaxed, multimodal retrieval."
>
> Why relaxed retrieval? When consciousness is relaxed, as it is in hypnosis, for example, long-term memories are more readily recalled. (EVT, p. 91)

The method combines two interventions. The first is relaxation.

> The importance of relaxed attention [. . .] to visual recall can be explained in terms of cognitive structures. Unlike videotape, cognitive structures encode information in every sensory mode and in the mode of feeling. Much of this intersensory and feeling input is assimilated subconsciously. [. . .]
>
> As with videotape, cognitive structures can be replayed accurately only in the same mode that they were recorded. Thus you must relax consciousness to replay memories partially recorded subconsciously. (EVT, p. 91)

The second intervention is multimodal retrieval.

> Memory retrieval is also enhanced when recall is multimodal—that is, when all the sensory modes of imagination and the mode of feeling are called into the playback. (EVT, p. 91f.)

Here is an example of the method, applied to enhance the recall of an apple.

> Close your eyes and relax; direct your attention inward [. . .]. Now imagine that in your hand you have a delicious, crisp apple. Feel the apple's coolness; its weight; its firmness; its round volume; its waxy smoothness. Explore its stem [. . .]. Now bite the apple; hear its juicy snap; savor its texture, its flavor. Smell the apple's sweet fragrance [. . .]. With a knife, slice the apple to see what's inside. As you continue to explore the apple in detail, return occasionally to the larger context; see your hand, feel the soft breeze [. . .]. (EVT, p. 92)

A35) Memory performance is partially determined by the person's physiological body state, in particular their level of relaxation and cognitive control.

A36) When a person did not actively and consciously assimilate a perception by the time of the original experience, chances of recall can be increased through relaxation next to multi-modal retrieval techniques.

D12) Relaxed multimodal retrieval is a method that aims to facilitate the recall of content that was not consciously processed by the time of the original experience.

Of course, McKim also trains mindful perception in order to improve memory performance. Here, multimodal perception is key.

> Repeat the previous exercise with a real apple instead of an imaginary one. Savor the apple slowly and pleasurefully, with all of your senses. [. . .] After eating it, recall the apple in all sensory detail. (EVT, p. 92)

A37) Training mindful, multimodal perception is a means to improve memory performance and thereby creative capacity: Only those experiences that a person can retrieve from memory in one way or other can inform her creative solutions.

4.4 A Theory of Representation Systems

Related to McKim's theories of attention and memory is also his account of representation systems. Once again, he explores the role of different sensory-modalities and why it is important for creative thinkers to be versatile in accessing them all.

As in other fields, McKim builds on works of his predecessor John Arnold, where he adds both developments of theory and practice. This was clearly in line with Arnold's hopes and expectations, who had asked McKim to develop visual thinking classes in addition to Arnold's already established courses.[3]

Notably, Arnold taught quite often methods for the creative process that included a strong invocation of verbal information processing. For instance, he taught students to start off from feelings about a problem domain (e.g., frustration, a feeling that "something is wrong"). Then they should probe different verbal formulations of the problematic situation, until a promising problem view and a respective, creative project was found (e.g., Arnold 1959/2016, p. 94). Thus, Arnold taught students to translate emotionally represented problems into verbally represented problems.

Verbal representations allow uniquely fine-tuned explorations of potential project avenues. Up to the present, design thinking uses the power of language to explore different problem accounts, and to unleash pinpointed creative endeavours. Methodologically, this power of language is harnessed for instance by formulating different How-Might-We questions or Point-of-View statements (d.school 2010). Another recent example is provided by Kelley & Kelley:

> For example, in retail environments, we've discovered that if you change the question from "how might we reduce customer waiting time?" To "how might we reduce **perceived** waiting time?" it opens up whole new avenues of possibility, like using a video display wall to provide an entertaining distraction! (Kelley and Kelley 2013, p. 23, emphasis added)

[3] Personal notes of William J. Clancey of a conversation with Robert McKim on January 31, 2018.

In this example, a single word in the problem description—"How might we reduce (perceived) customer waiting time?"—entails a huge difference for subsequent project trajectories, for creative missions and likely solutions (what in design thinking theory is often called the "solution space"). Language seems to be an almost ideal medium to make such precise distinctions.

M7) Language allows pinpointed differentiations of multiple potential creative projects in a problem domain; minor changes in verbal accounts of a problem open up greatly differing solution spaces.

Yet, how about other ways to represent information? Arnold had already added a couple of drawings here and there in his treatises, before McKim began to elaborate the concept of visual thinking.

In *Creative Engineering*, a discussion by Guilford comes closest to anticipating a theory of information representation systems.

> [It is important to note] the kind of content or material, or the form in which [. . .] information exists: figural, symbolic, or semantic. Figural content is information in concrete form, as perceived through the senses or as recalled in the form of images. [. . .] Symbolic content is in the form of signs, which have no significance in and of themselves. Examples are letters, numbers, musical notations, and so on. Semantic content is in the form of meanings to which words are commonly attached, hence it is most notable in our verbal thinking. (Guilford 1959/2016, p. 153)

McKim concerns himself much more intensely with representation systems in EVT. His discussion goes beyond Guilford's short overview in several important regards, including the number of representation systems that are distinguished. Already in his guest essay in *Creative Engineering*, McKim had highlighted the importance of emotions or feelings for human creative design activities (cf. von Thienen et al. 2019—where the topic was discussed under the headline of 'felt design responses'). Thus, unsurprisingly, McKim adds emotions/feelings as another representation system. Furthermore, when information can be processed via the visual sense channel, then of course it can also be processed via other sense channels. "Cognitive structures encode information in every sensory mode and in the mode of feeling" (p. 91). Here, McKim's theory of memory and his theory of representation systems overlap.

> A well-known thinking vehicle is language [. . .]. Other vehicles of thinking are non-verbal languages (such as mathematics), sensory imagery, and feelings. (EVT, p. 3)

According to McKim's treatment of the topic . . .

A38) Representation systems are characterized in a twofold way: (1) how information is processed cognitively and (2) how information is represented externally.

Examples of representation systems are provided in Table 1.

Here is an example concerning the visual sense channel, where McKim introduces the concept of "visual imagery" (Fig. 4).

> Visual thinking is carried on by three kinds of visual imagery:
>
> (1) the kind that we *see* [. . .]
> (2) the kind that we *imagine* [. . .]
> (3) the kind that we *draw* [. . .]. (EVT, p. 6, emphasis in the original)

Table 1 Examples of representation systems

Representation system	Sample cognitive process	Sample externalization
(Verbal) Language	Listening to a conversation, reading	A spoken or written sentence
Mathematics	Calculating	A mathematical proof
Visual imagery	Seeing	A sketch or sculpture
Auditory imagery	Hearing	A played song
Tactile imagery	Experiencing softness	Products made of specific materials
Kinaesthetic imagery	Sensing the body in motion	Dance
Emotion/feelings	Experiencing pleasure	Gesture

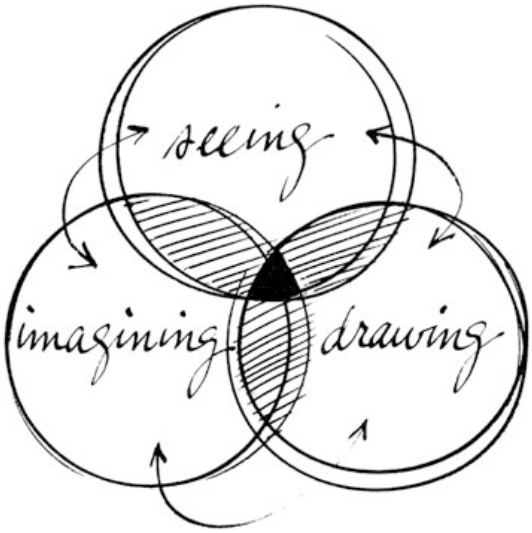

Fig. 4 With this Venn diagram, McKim visualizes "the interactive nature of seeing, imagining and drawing" (image re-printed from EVT, p. 6)

Notably, these three kinds of imagery correspond to the major chapters in EVT: Seeing, imagining, idea sketching.

Visual imagery covers all cognitive processing based on the visual sense channel.

D13) Representation systems can be identified on the basis of sensory modalities (e.g., seeing, hearing) and cognitive processing systems (e.g., language processing, mathematical processing).

When a person perceives something in a particular representation system, it can be something found in nature (a tree, a stone etc.) or something man-made.

By contrast, externalizations in representation systems are necessarily man-made. They are (usually intentional) expressions of thought in some medium that can be perceived with one's senses. Prototypical examples are physical, man-made artefacts to convey problem-views or solution ideas in the creative process.

> Consider the sculptor who thinks in clay, the chemist who thinks by manipulating three-dimensional molecular models, or the designer who thinks by assembling and rearranging cardboard mockups. Each is thinking by seeing, touching, and moving materials, by externalizing his mental processes in a physical object. (EVT, p. 40)

Externalizations can take many different forms. For instance, "visual ideas can be expressed by acting them out, talking about them, writing them down, constructing them directly into a three-dimensional structure—and drawing them" (p. 116).

D14) An externalization is a (typically intentional) expressions of thought in a medium that can be perceived by the senses.

D15) The sensory modality and/or cognitive processing system used to perceive an externalization identifies the representation system that is being deployed.

As McKim's respective theorising is essential for his discussion of prototyping and prototyping materials, this topic is treated in further detail in Sect. 7, which covers McKim's account of how to design places that facilitate creative work.

Clearly, in everyday life, representation systems are often not used disjunctively. When listening to another person, we typically engage in verbal information processing, at least when the other person's language is understandable to us. There is also additional auditory information regarding the tone of the voice and the "melody of speech" (intonation), next to possibly other sounds in the background. Moreover, recognising an angry or gentle voice can result from emotional information processing. Similarly, visual stimuli do not normally entail disjunctively visual thinking. Here, once again, McKim highlights the role of memory.

> Perceptual reality [...] [i.e. the way in which you perceive reality] combines what you know with what you see, and that knowing is polysensory. You perceive a chair: polysensory memories merge; you perceive a chair that is solid, pleasant to touch, and soft to sit in. (EVT, p. 70)

A39) When we perceive the world, representation systems are typically not used in isolation and disjunctively; already the visual perception of a single object usually activates several representation systems (here: memories concerning different sensory modalities) in parallel.

Yet, when confronted with problems to solve, McKim emphasizes that people often select specific representation systems to tackle the task, which can be more or less helpful. He invokes problem exercises to help people become aware of the representation systems they personally prefer and choose intuitively. By contrast, people often neglect certain other representation systems that might be helpful at least for the solving of some other problem types. Most people have strong preferences and are by no means equally facile in different systems.

> Observe your mental processes as you attempt to solve this problem: "a man and a girl, walking together, step out with their left feet first. The man walks three paces while the girl walks two. When will both lift their right feet from the ground simultaneously?" [...]
>
> Did you, for example, talk to yourself about the problem sub-vocally? If so, the vehicle of your thinking was language. Or did you walk two fingers of each hand [...] or feel vague walking sensations in your muscles? If so, your thinking vehicle was sensory imagery. [...] The answer to the puzzle [is]: Never. (EVT, p. 3f.)

McKim, together with his colleague James Adams at Stanford Engineering, used such puzzles to illustrate the importance of selecting suitable representation systems for the understanding of problems and finding solutions. Regarding this same puzzle

of two persons walking, Adams remarked:

> This is a good problem to solve with visual thinking. The live experiment with another person, a drawing, or a musical rhythm analogy will all work well. The mathematical approach will work, although it is somewhat circuitous. Verbalisation, once again, will not get you very far. (Adams 1974, p. 65)

For other problems, different representation systems can be more fruitful. Thus, the appeal is to use representation systems mindfully, to acquire proficiency in different systems and to be flexible in one's choices.

A40) Representation systems differ in the problem-solving opportunities they engender; different representation systems allow people to solve different kinds of problems.

Notably, once again a full-body perspective is invoked regarding problem-solving. Specifically, problem-solving by means of sensory imagery is described as a "full-body undertaking." In the puzzle concerning two persons walking side-by-side, solution approaches in which people move fingers like feet on a table, or even endeavour a two-person live experiment, engender insights by means of body motion.

M8) The theory of representation systems pursues an embodied cognition approach; the role of the body—from sensory organs, over body states to the body in motion—is analysed in relation to creative problem solving.

One of the reasons why McKim finds it utterly important for people in a creative project to invoke many different representation systems, is because he holds a respective (bio-)psychological theory about the emergence of creative breakthrough ideas. Here, the basic notion is that creative breakthroughs often obtain when knowledge from a seemingly disparate field is brought to bear on a problem that is currently to be solved—a belief that has received much support from recent research (von Thienen 2019; cf. also the discussion of "processing seemingly irrelevant information" in the chapter "Neurodesign Live").

McKim discusses pertinent cognitive processes under the headline of "hidden likenesses," which need to be discovered. Notably, expectations are high regarding creative breakthroughs that obtain from the discovery of such hidden likenesses. "The discoveries of science [and] art are explorations—more, are explosions of hidden likenesses" (EVT, McKim agreeing with and quoting Bronowski, p. 106). "It is the same act in original science and original art" (p. 106.).

One example is a famous creative breakthrough that August Kekulé achieved in the field of chemistry. He noted and explored the potential likeness of a snake biting its tail (thus forming a ring), and the benzene molecule. Against expectations, the molecule turned out to have a ring structure. (This example is discussed in further detail in Sect. 5).

A more mundane example helps to lay out the presumed role of different representation systems for the discovery of hidden likenesses.

> In the verbal arts, a hidden likeness is encoded in a simile, analogy, or metaphor. Similes and analogies point to likenesses explicitly (for example: "The Renaissance was like the opening of a flower"); metaphors do so implicitly ("the Renaissance blossomed.")

> On the usual conscious level of language, of course there is no likeness between flowers and the Renaissance. The hidden likeness is on a deeper level, beyond words, **where sensory and emotional memories associated with the two words overlap**. (EVT, p. 106, emphasis added)

By using the full spectrum of available representation systems—including especially the often neglected representation systems of sensory and emotional processing—creators increase their chances of discovering hidden likenesses. This, in turn, should make creative breakthroughs much more likely. Once again, however, relaxation abilities and more generally flexibility in thinking levels will also be needed.

> Access to vivid sensory and affective memories, to that portion of memory containing material for the discovery of vivid and illuminating hidden likenesses, often requires the relaxation of conscious control. (EVT, p. 107)

A41) Versatility in different representation systems, plus flexibility in levels of thinking, strongly increases the chances of a creator to develop breakthrough insights.

A42) In biopsychological terms, hidden likenesses are discovered when memories concerning seemingly different topic domains get activated jointly, based on similarities of sensory and affective experiences in the domains.

The concept of hidden likenesses informs design thinking up to the present. It underlies, for instance, the method "analogous empathy" described in the Bootcamp Bootleg (d.school 2010, cf. Fig. 5).

Representation systems will be treated in further detail in an upcoming review of Conceptual Blockbusting (Adams 1974) in this series on design thinking history.

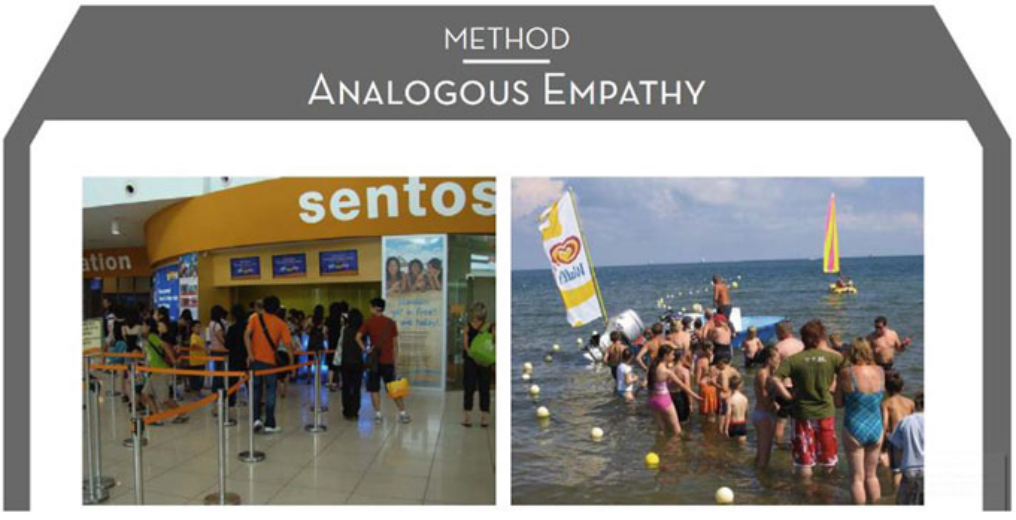

Fig. 5 With the present-day design thinking method "analogous empathy," creators discover and explore "hidden likenesses" between two or more seemingly different topic domains [image reprinted from d.school (2010, p. 12)]

5 The Concept of Ambidextrous Thinking

Ambidextrous thinking is a concept coined by McKim in his discussion of visual thinking, which becomes central for the history of design thinking. Later on, Rolf Faste—a successor of Robert McKim at Stanford's Product Design Department—will advance former "visual thinking" classes towards a curriculum on "ambidextrous thinking." This title serves to emphasise even more the role of diversified sensorimotor engagements beyond the well-explored channel of visual information processing for purposes of creative engineering.

> ME 313, Ambidextrous Thinking, was created in 1988 to meet the needs of incoming Masters degree students in the programs of Mechanical Design, Manufacturing Systems Engineering and Product Design. [. . .] "Ambidextrous" means the ability to use both hands [. . .] and by extension, use of the whole body, in creative thinking. [. . .] ME313 grows out of a course called Visual Thinking which has been required of all undergraduate Mechanical Engineering students for over thirty years. "Ambidextrous Thinking" was chosen as the name because it alludes to more than visual thinking [. . .]. (Faste 1994, p. 1)

Years later, the concept of ambidextrous thinking and respective curriculum practices were advanced under a novel headline once again: design thinking. Yet, this part of design thinking history will be reviewed in another chapter of this series.

McKim's concept of "ambidextrous thinking" was inspired by ideas of Jerome Bruner, Abraham Maslow, Ulric Neisser and John Arnold. McKim combines their ideas in a novel framework of thought and practice.

Jerome Bruner's *On Knowing: Essays for the Left-Hand* (1962) discussed ancient symbolisms of the left versus right hand. According to this symbolism, the right hand is associated with "the doer":

> The right is order and lawfulness, *le droit*. [. . .] Reaching for knowledge with the right hand is science. [. . .] [T]he right hand represents discipline, logic, objectivity, reason, judgement, knowledge, skill, and language. [. . .] [T]he symbolic right hand holds the tools necessary to develop, express, and realise ideas, to bring them into the world of action. (EVT, p. 18)

By contrast, symbolically the left hand is associated with "the dreamer":

> Though the heart is virtually at the center of the thoracic cavity, we listen for it on the left. Sentiment, intuition . . . Should we say that reaching for knowledge with the left hand is art? [. . .] Developing the symbolism further, the left hand represents openness, receptivity, subjectivity, playfulness, feeling, motivation, and sensory and imaginative processes [. . .]. The symbolic left hand is open to fresh impressions, hunches, and subconscious levels of thinking [. . .]. (EVT, p. 18)

According to this symbolic view of left versus right hand, neither one will achieve great creative solutions alone. Novel and promising ideas need to emerge from the left, but to put them into action requires skills of the symbolic right hand. Accordingly, Bruner proposes more than multidisciplinary teams with symbolically left and symbolically right-handed team members, or "institutionalised cultural bridges" (EVT, p. 18). According to Bruner, there would have to be "an internal

transfer from left to right" (ibid.) in each creative individual. McKim picks up on this notion and elaborates it to a comprehensive concept of ambidextrous thinking.

> Bruner's call for an internal transfer from left to right hands implies a need to integrate the artist and scientist within each one of us [...]. The individual who is able to bridge the inner messages of his left hand over to his form-giving, outward-oriented right hand, is, to carry the left right symbolism one step further, ambidextrous in his thinking. Truly creative people in every field are ambidextrous—that is, capable of receiving with the left and transferring to and expressing with the right. (EVT, p. 18f.)

D16) Ambidextrous thinking means that a person is proficient in diverse thinking strategies and she combines them in effective ways: from symbolically "left-handed" approaches (such as being spontaneous, open to dreams, playful and intuitive) to symbolically "right-handed" approaches (such as following organised, well-reasoned and educated work strategies).

A43) In order to achieve great creative outcomes, there is not only a need for diverse teams, but each creative individual needs to be capable of diverse thinking strategies; each individual needs to be capable of ambidextrous thinking.

Up to the present, this outlook is pursued in design thinking education. While teams are assembled to be diverse, there is not a lot of role segregation in practice. All team members make personal experiences in the field (fostering "left-handed" cognitive processing). All team members also engage in synthesis work, often including analyses in a 2×2 matrix or using other organised approaches (fostering "right-handed" cognitive processing).

To McKim, this theoretical framework of ambidexterity provides a rich background against which he offers, and experiments with, practical trainings. His students are engineers, well-versed in symbolically right-handed activities, such as mathematical calculations or model building. To balance these skills, McKim emphasises symbolically left-handed activities in the curriculum. Whether people are encouraged to train acute perception or daydreaming in the Imaginarium, whether they are asked to take a relaxing bath, doodle in their notebook or conduct stretching exercises as recommended in EVT, or whether there is even a probing of drug effects on creative performance (Harman et al. 1966)—an overarching intention is to induce more symbolically left-handed processes in addition to right-handed cognitive processing. In particular, McKim encourages more intuition-driven, spontaneous, not consciously controlled ideation processes.

While the terminology of ambidextrous thinking may seem unique, the underlying theoretical framework is in fact a classic one (Clancey 2011; von Thienen and Meinel 2019). Many authors have made similar distinctions, akin to the symbolic left versus the symbolic right, which need to work together in order to advance masterful creative outcomes. Table 2 provides a brief overview of terms used by different authors in the design thinking tradition.

Once embracing Bruner's notion of left versus right hand, McKim elaborates the concept of ambidextrous thinking especially based on the works of Abraham Maslow, who had been another guest expert in John Arnold's *Creative Engineering* seminar. McKim discusses the same claims and content that Maslow had personally presented in the 1950s at Stanford, though EVT provides references to more recent

Table 2 Different authors have described two kinds of creativity approaches, one associated with creative leaps and heightened creativity, the other associated with technical sophistication and a "polishing" of details [adapted from von Thienen and Meinel (2019)]

	Creative leaps, heightened creativity	Sophistication and polishing
John Arnold (1959)	Inspired creativity approaches	Organized creativity approaches
Robert McKim (1959)	Felt design responses	Reasoned design responses
Abraham Maslow (1959)	Primary creativeness	Secondary creativeness
Jerome Bruner (1962) and McKim (1972)	Symbolic left hand	Symbolic right hand
Rolfe Faste (1994)	Right mode thinking (alluding to the right brain hemisphere)	Left mode thinking (alluding to the left brain hemisphere)

writings of the author. Maslow does not use the terms "left hand" versus "right hand," but instead writes about "primary" versus "secondary" creativeness.

In Maslow's description, secondary creativeness is typically exhibited by adults, not young children. A classic example would be an effective scientist who is a rather "rigid" or "constricted" person. Someone who exhibits secondary creativeness deals with the world "logically, objectively, and in orderly fashion" (EVT, p. 19). Syndromatically, an adult who is capable of secondary creativeness only "has lost intimate contact with senses, feelings, and his inner fantasy life" (ibid.). Secondary creativeness alone does not yield creative leaps. It is more a matter of polishing, fine-tuning and making gradual step-by-step progress. This contrasts to primary creativeness.

> Maslow, in describing "primary creativeness," agrees with Bruner's statement that "the great hypotheses of science are gifts carried by the left hand." According to Maslow, primary creativeness "comes out of the unconscious." It is the result of [our] ability "to fantasy, to let loose, to be crazy, privately." Primary creativeness "is very probably a heritage of every human being and is found in all healthy children." [...] Conscious primary creativeness, according to Maslow, is "lost by most people as they grow up." Most people, that is, whose society demands reality-adjusted thinking only, and whose education has been almost exclusively "right-handed." (EVT, p. 19)

Here, McKim finds further theoretical support for his endeavour to integrate more dreaming activities in the strategy repertoire of engineers, in the service of creativity. McKim continues in his review of Maslow's remarks.

> We all nightly experience primary creativeness in our dreams: "in our dreams, we can be... more clever, and wittier, and bolder, and more original ... with the lid taken off, with the controls taken off, the repressions and defences taken off, we find generally more creativeness ...." (EVT, p. 19)

Like Bruner, Maslow also points to the necessity of integration—a message that McKim endorses wholeheartedly. "A truly integrated person can be both secondary and primary; both mature and childish. He can progress and then come back to

reality, becoming then more controlled and critical in his responses" (Maslow quoted by McKim in EVT, p. 19).

One reason why this framework of ambidextrous thinking becomes so important in EVT, is because it interplays straightforwardly with McKim's theory of representation systems. Here, it underpins the importance of visual thinking for high levels of creative performance. When people use the visual representation system, they are in touch with their senses (at least the visual sense channel), which is said to advance primary creativeness/symbolically left-handed thinking. By contrast, when people predominantly use representation systems of mathematics or verbal languages, this is assumed to advance secondary creativeness/symbolically right-handed thinking.

> The verbal thinker, especially, tends to think in this second-hand way: he skilfully manipulates symbols but rarely makes full contact with his own primary resources. Visual thinking is a marvellous antidote for this sterile, one-sided kind of thinking. Or more correctly, visual thinking with its symbolically left-handed, primary-process origins, is a vital complement to symbolically right-handed, secondary-process thinking-by-words-and-numbers. (EVT, p. 21)

Maslow describes a prototypical example of overreliance on verbal thinking and resulting "mere" secondary creativeness. He portraits a scientists who spends his academic career pre-dominantly by working with texts: reading and writing. In this form of academic life, primary, sensorimotor experiences in the world are barely sought. Thus, primary creativeness does not get stimulated.

> As Maslow suggests, the individual [scientist] who is capable only of "secondary creativeness" [...] stands on other people's shoulders, thinking about the written thoughts of someone who, in turn, was writing about an idea that he had read—and so on. (EVT p. 21)

A44) Visual thinking is a symbolically left-handed activity, which facilitates primary creativeness (i.e. heightened creativity; creative leaps).

A45) Verbal and mathematical thinking are symbolically right-handed activities, which facilitate secondary rather than primary creativeness (i.e. technically sophisticated solutions mostly in existing paradigms).

Against this background, the unique relationship between design thinking and libraries can be reconsidered in theoretical terms. In an empirical research study, design thinking experts had named libraries amongst the "top three environments" that would antagonize design thinking (von Thienen et al. 2012). Moreover, existing design thinking facilities—even when located at universities—typically do not encompass large "university-typical" libraries. McKim's reflections provide a theoretical background, which helps to elucidate present-day thoughts of design thinkers about libraries: An environment that is predominantly filled with texts can make it difficult for visitors to make first-hand experiences immersed in the world, as one is rather reading second-hand about the experiences of others. Texts and mathematical treatises court verbal and mathematical processing, as opposed to immersive sensorimotor experiences in the world. At the same time, McKim's overarching purpose was to encourage flexibility, i.e. the use of all representation

system in balanced ways. This might argue in favour of libraries to be used for some time, carefully balanced with immersive polysensory experiences at other times.

According to the theory of ambidextrous thinking . . .

M9) Environments need to promote sensorimotor engagement and symbolic processing in carefully balanced ways in order to promote both primary and secondary creativeness (ambidextrous thinking), to foster highest levels of creative performance.

M10) Environments that predominantly provide texts, such as libraries, bias towards symbolic information processing; to encourage ambidextrous thinking, they need to be complemented by other environments that foster poly-sensory experiences in the world.

M11) The theory of ambidextrous thinking elaborates creative mastery as a phenomenon of embodied cognition; the individual is said to achieve highest levels of creative performance only when she seeks out, and integrates, sensory-motor experiences with symbolic information processing.

In EVT, McKim also turns to history and reviews case examples of outstanding innovators to find characteristic patterns in their approaches. Before him, in a similar manner, John Arnold had reviewed works of famous creative persons to identify distinctive work patterns. McKim emphasizes two regularities: In the cases he reviews, all innovators benefitted from visual thinking in their work, and they used visual approaches as part of ambidextrous thinking strategies:

> In chapter 1, scientists Fleming, Watson, Kekulé, and Einstein and engineers Tesla and Houbolt are revealed as eminently ambidextrous. Kekulé's dream of a snake biting its tail, for example, is left-handed, while his verification of this insight in his laboratory and within the theoretical framework of chemistry is the work of his disciplined right hand. (EVT, p. 19)

In the case of the chemist Kekulé, for instance, a description of the creative process was provided by the chemist himself. Kekulé had provided an account of how he had tried to figure out the structure of the benzene molecule for a long time. Then, sitting in front of a fireside, in a state of dreaming he experienced the visual imagery of a snake biting its tail. This engendered Kekulé's idea that the benzene molecule might have a ring structure, which he later verified in chemical experiments. Analysed in the framework of ambidextrous thinking, and McKim's theory of creativity more generally, this episode displays a number of characteristic elements. Kekulé relaxes. He dreams. He experiences visual imagery. Thoughts emerge from automatic/non-conscious levels of processing (not only from deliberate thinking with attention "on task"). All this is essential for Kekulé to achieve a creative leap. However, a symbiosis is required between these symbolically left handed activities, and the symbolically right handed rigour of a capable scientist. It takes ambidextrous thinking to achieve the creative breakthrough.

> Again, it is not a question of one or the other: sensory imagination and symbolic thinking are complementary, each performing mental functions that the other cannot. [. . .] Specifically, the creative thinker is ambidextrous: he uses his symbolic left hand as well as his right [. . .]. Learning to think visually is vital to this integrated kind of mental activity. (EVT, p. 22)

6 The ETC Model for Creative Work: Express, Test, Cycle

In addition to more general reflections, as concerning the concept of ambidextrous thinking, McKim also provides immediately practical advice. One notable contribution is his "ETC model" to facilitate creative processes. The acronym stands for Express (Sect. 6.1), Test and Cycle (Sect. 6.2).

As one of the first visualisations in our work tradition, the ETC model introduces bold graphic circles to highlight the essentially iterative nature of creative work. Figure 6 compares McKim's ETC model to a more recent design thinking process model.

Markedly, the ETC model is only concerned with a very brief passage in the overall creative process, namely with the stages of ideation and testing prototypes. Clearly, this does not indicate McKim's overall treatment of creativity was this limited—it was not. In his Advanced Product Design courses, McKim introduced elaborate need finding exercises, where participants went out to meet potential users, for whom novel products might be designed. In this context, he advanced methods that are used up to the present day for creative process phases prior to ideation. Moreover, courses such as Product Design and Presentation (112c) offered by McKim carefully considered methodologies to advance final prototypes towards real-world products. Here and in Advanced Product Design, the concern was to make a big impact in the world, which is nowadays treated in the final

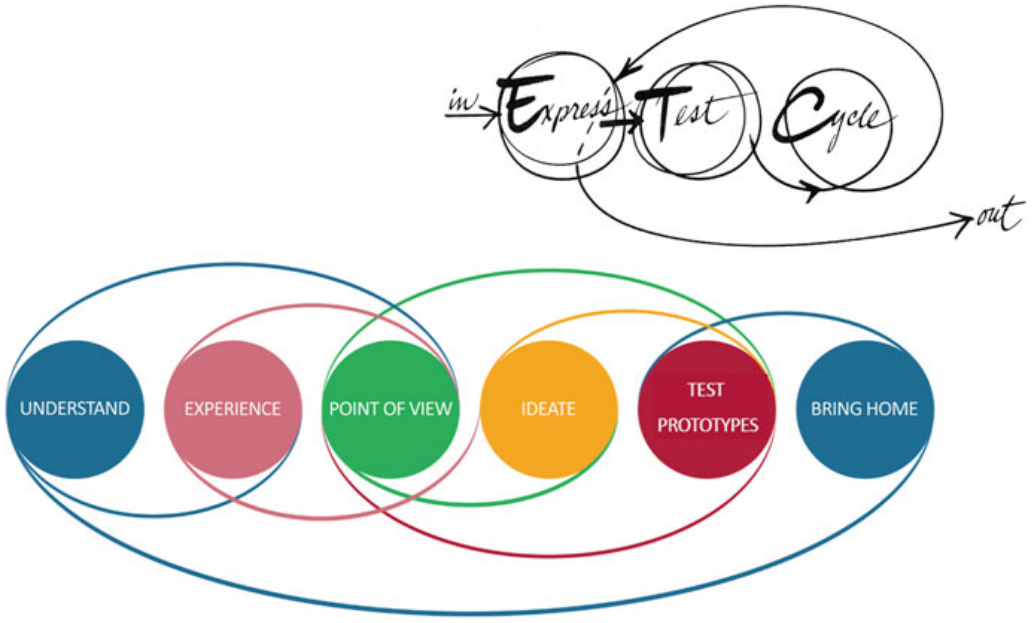

Fig. 6 The ETC model is only concerned with the stages "ideate" and "test prototypes" of a recent-day design thinking process model. Graphically, in the ETC model, circular lines connecting different process phases underscore the essentially iterative nature of creative work. This graphic element is used up to the present to communicate the need for iteration in creative processes

"bring home" phase of creative projects. Thus, early and late stages of the creative process are simply not the core topic of EVT and the ETC model. Even so, McKim's theoretical treatments reveal unmistakably, how important objectives of "understanding," "experiencing," probing "points of view" and "bringing home big ideas" are for his overall account of creativity.

Regarding the objective of *understanding*, McKim emphasises the importance of developing "correct," "adequate" accounts of situations, in order for thinking to be productive. "Since thinking is essentially information-processing, we cannot expect productive thinking when information is incorrect, inadequate, or tucked away in an unavailable crevice of memory" (EVT, p. 2). He continues, "Each reader must seek these [. . .] conditions without much aid from this book: [. . .] information requirements vary with each problem" (p. 2). At the same time, EVT provides theoretical reflections and practical advice in numerous sections, as to the difference between productive versus non-productive thinking, how readers can recognise unproductive thinking phases, and how they can redirect their own thoughts towards more fruitful trajectories.

The objective of *experiencing* is a key topic throughout EVT. McKim explains how immersive experiences with great perceptual awareness regarding all human sense modalities are essential for high levels of creative performance. Without this mindfulness, thinking is bound to abstract, symbolic processing, which all too often merely reproduces stereotypes. Individuals who only use a few representation systems, where specifically sensory-motor systems and feelings are disregarded, cannot expect to escape language-bound, culturally conveyed traditional concepts that advance thinking inside the box. "Taught always to name what they see, many students learn to label the [. . .] stimulus too quickly, before they see it fully" (EVT, p. 24). Thus, asked to draw a tree, they "can only draw a primitive green lollipop" (ibid.)—a tree stereotype. McKim seeks to help students escape the rut of stereotyped symbolic processing, by gaining immersive experiences in the world and learning to be mindful about the here-and-now.

Similarly, *points of view* are a re-current, often addressed topic in EVT. The term McKim uses most regularly in this context is "recentering." He explains how personal knowledge and training impact the way in which we see the world. "A dentist and a psychologist see the same smile differently" (p. 83). Moreover, communities have a strong formative effect upon perception, and emotional blocks prevent us from seeing things differently. Here, McKim adds psychological theories of perception concerning a topic discussed in his *Creative Engineering* guest essay before (where he had addressed cultural need hierarchies; cf. McKim 1959/2016; von Thienen et al. 2019).

> To judge whether your own vision has been stereotyped by fear, be aware of your emotions with regard to "unacceptable" images. For example, be aware of your feelings when your clothing is somehow conspicuous. [. . .] More important, ask how far you could depart from the visual norm of fashion without having real reason to fear losing friends, losing your job, or even being "put away" in a mental institution. Social coercion patterns perception more powerfully than we are usually aware. (EVT, p. 45)

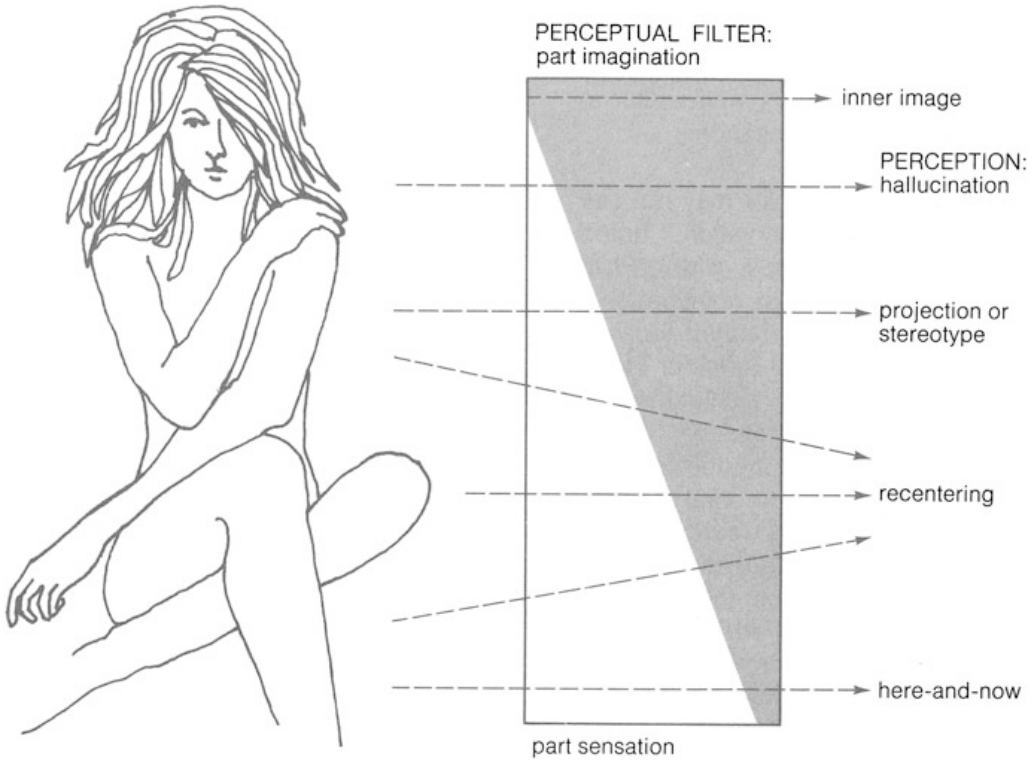

Fig. 7 Recentering, the act of exploring a novel point of view, is very close to mindfulness of the here-and-now. There are many ways to recenter. By contrast, when a person perceives based on stereotypes, or when she hallucinates, her perceptions are dominated by imagination (image reprinted from EVT, p. 44)

Against culturally pre-determined views, McKim holds: "Healthy perception is not stuck in a cocoon of cultural conditioning; it is open, flexible, and alive" (p. 45).

> The key concept is *flexibility*. The person who can flexibly use his imagination to recenter his viewpoint sees creatively. The person who cannot budge his imagination to see alternative viewpoints, by contrast, experiences only a one-sided, stereotyped vision of reality. (EVT, p. 44)

Figure 7 provides a graphical illustration of how McKim understands recentering, i.e. the healthy and flexible exploration of different possible viewpoints. Notably, recentering is very close to mindfulness of the here and now. The individual uses some imagination to explore different possible points of view. However, these different viewpoints are all rather reality-adjusted; they are all viable. There is a large distance to hallucinations, where perceptions are dominated by imaginations that are not reality-adjusted. Moreover, recentering is flexible; there are many ways (arrows) of recentering. This contrast to perception following the single trajectory of a dominant stereotype.

> Recentering is characterised by the flexible ability to change from one imaginative filter to another. The recentering perceiver might, for example, see the naked lady as would a sculpture (perhaps assessing the formal quality of her pose), as would an advocate of women's liberation (she's being exploited), then as the lady herself (I feel a bit chilly), and so on. (EVT, p. 44)

D17) Recentering means to perceive something from a novel viewpoint.

Methodologically, to train people's abilities of recentering, McKim invokes exercises such as "making the familiar strange" or verbal "re-labelling"—approaches used occasionally in design thinking up to the present.

Regarding the *bring home* phase in creative projects, McKim provides many pages of examples in EVT that depict and compare externalisations/models/prototypes of successful creators from earlier and later work stages. He emphasises how prototypes usually evolve from rough to refined. Quite often, there is a trajectory from 2D sketches to 3D models. Final solutions need to consider many details of appeal and usability, such as the sensory feeling of the materials used, the exact positioning of knobs etc.—topics already elaborated in McKim's *Creative Engineering* guest essay (McKim 1959/2016; von Thienen et al. 2019).

M12) The ETC model only covers the phases in a creative project concerned with ideation and testing prototypes; McKim's overall work, however, covers the full palette of process phases distinguished in present-day design thinking processes models, from understanding a problem to bringing home big ideas.

Amidst all phases and objectives in creative work comes the ETC model: Express, Test and Cycle. As in present-day design thinking compilations, the model is introduced together with dedicated methodological suggestions regarding each phase, structurally very similar to the Bootcamp Bootleg (d.school 2010).

To understand suggested methods of the ETC model theoretically, especially in the express phase, it is important to bear in mind that McKim uses the model to translate the concept of ambidextrous thinking into educational practice. Here, the major methodological question emerges how creators can bridge their symbolically left and symbolically right hand. How is it possible to receive inspiration from automatic, non-deliberate cognitive processes and then create something tangible that facilitates deliberate creative work?

To recall, this is the concept of ambidextrous thinking, which McKim sets out to translate into practical exercises and methods for education in class: "The symbolic left hand is open to fresh impressions, hunches, and subconscious levels of thinking" (p. 18). "The symbolic right hand holds the tools necessary to develop, express, and realise ideas, to bring them into the world of action" (ibid.). "The individual who is able to bridge the inner messages of his left hand over to his form-giving, outward-oriented right hand, is [. . .] ambidextrous in his thinking. Truly creative people in every field are ambidextrous—that is, capable of receiving with the left and transferring to and expressing with the right" (p. 19).

6.1 Express

"'Ex-press' means to **press out**. Idea-sketching is a way to express visual ideas, to literally press them out into tangible form" (p. 116, emphasis in original). When interesting ideas emerge in the mind, McKim highlights their elusive and quickly changing character. The creative person needs to take immediate behavioural action in order to not lose track of the idea.

Creating rough sketches seems to be an ideal technique to capture visual ideas: Rapid Visualization.

McKim describes the experience:

> ... the model for idea-sketching is an inner event visible only in the mind's eye, rarely fully formed, and easily lost to awareness. The visual thinker who uses drawing to explore and develop ideas makes many drawings; idea-finding and formation is not a static, "one picture" procedure. He also draws quickly, ideas rarely hold still; they readily change form and even disappear. (EVT, p. 116)

A46) An emerging idea is dynamic and indefinite; the individual needs to externalize it rapidly in some representation system, before it vanishes from awareness.

The objective of having to be highly sensitive to one's own imagery and extremely fast in order to record novel ideas is also underpinned by a distinction McKim invokes, where he emphasizes different methodological necessities in earlier versus later phases of idea development.

> Graphic ideation has two basic modes: exploratory and developmental. In the exploratory mode, the visual thinker probes his imagination with his marker, seeking to touch and record the vague and elusive imagery that usually accompanies the conception of a new idea [...]. In the developmental mode, the visual thinker gradually evolves a promising, though initially embryonic, concept into mature form. (EVT, p. 116)

D18) Exploratory ideation is concerned with the recording of emerging ideas; major methodological challenges include (a) recognizing novel ideas in one's constantly changing imagery and (b) being fast enough to record ideas before they are lost to awareness.

D19) Developmental ideation is concerned with the maturation of novel ideas; major methodological challenges concern the achievement of sophistication regarding an idea.

During exploratory ideation, the individual can choose among many different representation systems to record emerging ideas. McKim encourages readers to be mindful of different options they have. Even when novel ideas appear in the form of visual imagery, they can be captured in different formats. "Visual ideas can be expressed by acting them out, talking about them, writing them down, constructing them directly into a three-dimensional structure—and drawing them" (p. 116).

A47) Different representation systems can be used to capture emerging ideas.

The necessary speed to record novel ideas can be obtained by creating sketches, instead of detailed representations. Sketches can be engendered in many different

representation systems. Body-motion, verbal accounts, 3D models or 2D drawings can all be engendered in sketch-form.

> What are the characteristics of a sketch? Actors perform "sketches" that are customarily short and informal; writers "sketch out" their ideas in outline form and in rough, preliminary drafts; sculptors make rapidly executed "three-dimensional sketches" before proceeding to the final expression of their idea. In whatever form it takes, a sketch is typically (1) self-intended or directed to a small in-group, (2) concerned more with chief features than with details, and (3) performed spontaneously and quickly. Sketches that record the excitement of idea generation and formulation also often possess a vitality and freshness lacking in the final communication. (EVT, p. 116)

A48) To capture emerging ideas in any representation system, it is best to use rough sketches instead of detailed representations.

D20) A sketch is the representation of an idea or conceptualization in a form that is (1) meant for use by oneself or one's team only, (2) concerned more with chief features than with details, and (3) it is performed spontaneously and quickly.

Furthermore, any procedure of capturing emerging ideas thrives on psychological safety, which allows the creator to devote full attention to emerging ideas only. There need not be any "chatter" in the creator's mind as to what others might think, or what they might need to be told in order to understand and like an idea. The only concern for a creator to care about—the only focus of his voluntary attention—needs to be his own creative undertaking.

> Being his own audience, the graphic ideator enjoys certain freedoms [. . .]: he can sketch freehand, quickly and spontaneously, leaving out details that he already understands that he believes might concretize his thinking prematurely [. . .]; he feels free to fail many times on the way to obtaining the solution. (EVT, p. 117)

A49) (Graphic) Ideation is to be conducted in a state of psychological freedom or safety, where the creator does not think about perspectives of others; this helps individuals maintain voluntary attention on the ideation objective (not on social concerns); it helps individuals represent ideas before they get lost, and ultimately it increases productivity.

Psychological freedom or safety has also been a topic in design thinking research, where similar concerns have been highlighted as those described by McKim (Leifer and Auernhammer 2021).

(Graphic) ideation contrasts to (graphic) communication. Methodologically, communication concerns should be addressed in later process phases.

A50) (Graphic) Communication is to be conducted with a focus of attention directed towards social objectives; here, the key question is how to best present an idea so that other understand (and possibly like) it.

> Graphic ideation is not to be confused with graphic communication. The former is a formative process concerned with *conceiving and nurturing ideas*; the latter is an explanatory process concerned with *presenting fully formed ideas to others*. Graphic ideation is visually talking to oneself; graphic communication is visually talking to others. Graphic ideation precedes graphic communication in most instances: the visual thinker must first discover and develop an idea worth communicating. (EVT, p. 117)

Just like social communication concerns, self-critical reflections should also be silenced in the ideation phase.

> *Defer judgement*. Attempting to express and to judge ideas simultaneously is comparable to trying to drive a car with one foot on the accelerator and the other on the brake. (EVT, p. 118)

In this regard, McKim's discussion is very similar to that of Arnold in *Creative Engineering*—even up to the references he provides, to Guilford, Osborn and Schiller.

A51) To facilitate ideation, individuals need to defer judgement.

D21) An individual defers judgement during her own ideation process when she does not engage in critical reflections regarding herself, her ideas and her externalizations.

In this regard, McKim also mentions the importance of some basic skills in the externalisation process, such as drawing skills to capture visual ideas. Lacking skills easily induce judgemental thinking, and they can also have other negative consequences.

> The importance of drawing skill to the full expression of visual ideas must not be overlooked. Inadequate drawing ability has three negative effects on the *E*xpress phase of ETC: (1) a clumsy sketch usually evokes judgemental processes that restrict or stop idea-flow, (2) ideas that cannot be adequately recorded in sketch form are often lost, and (3) attention devoted to problems of drawing is attention diverted from idea-generation. (EVT, p. 119)

A52) Insufficient externalisation skills hamper the ideation process; they (i) induce judgemental thinking, (ii) lead to a loss of creative ideas as these are not captured fast or adequately enough and (iii) they hamper "voluntary attention," which should be uniquely devoted to ideas and not to (difficulties of) the externalisation process.

Yet, conducted in favourable psychologic conditions and with suitable skills, the externalization process itself facilitates ideation. Notably, this includes great flexibility on the key dimension of concrete versus abstract thinking.

> [There are] two important attributes of graphic ideation. First, the sketches are relatively "rough." They are not intended to impress or even to communicate; instead, they are a kind of graphic "talking to oneself." Second, [. . .] [i]dea-sketching, likely thinking itself, moves fluidly from the abstract to the concrete. (EVT, p. 10)

A53) One indicator of productive ideation is a fluent movement between concrete and abstract treatments of the topic, which can be identified in idea sketches.

An example of graphic ideation in contrast to graphic communication is provided in Fig. 8.

Overall, the phase of *E*xpression in the ETC model is concerned with several ends.

A54) The aim of the Expression phase in the creative process is to (i) identify ideas as they come to mind, (ii) externalise them adequately, so as to not forget about them and to (iii) facilitate the emergence of further ideas.

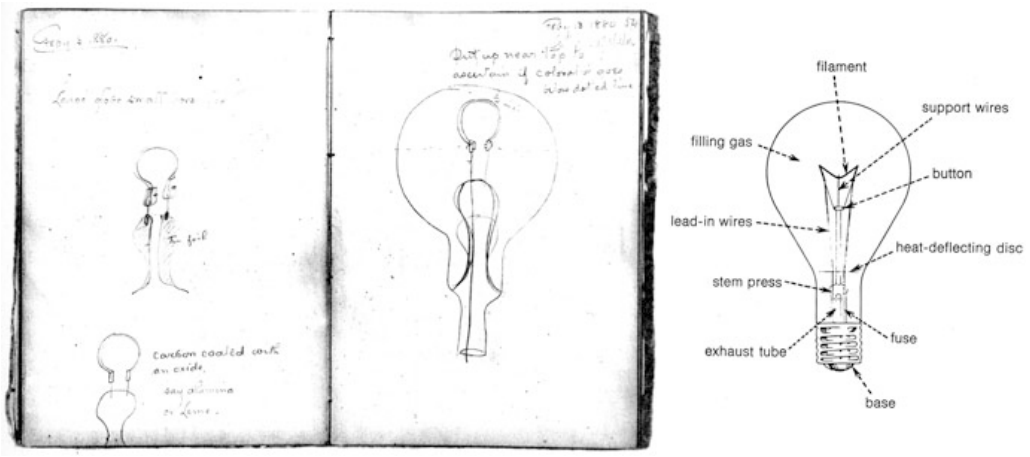

Fig. 8 The drawing on the left shows a notebook of Thomas Alva Edison, as an example of graphic ideation, depicting steps "in the birth of an idea" (EVT, p. 117). The drawing on the right is taken from a General Electric catalogue as an example of graphic communication (both images reprinted from EVT, p. 117)

From present-day design thinking perspectives, McKim emphasises quite strongly cognitive processes of the individual in the moment of recording ideas. Today, most commonly ideas are not recorded in moments of social withdrawal, but rather in situations of a team searching for good ideas jointly. Notably, this is clearly a situation McKim finds fully compatible with his account, as he specifically lays out how initial idea-sketching can be conducted in small "in-groups"—like design thinking teams.

With his reflections, McKim places a "magnifier" on a cognitive process that does occur individually—at the time of EVT and just as much today. When jotting down ideas for the first time, an individual takes action, and she does so as part of an ongoing cognitive processes, which can be studied as *her* cognitive process. McKim provides methodological advice for the person as to what can be important in this very brief moment when a novel idea takes shape in one's mind. The message sounds like a triviality accepted as a matter of course by present-day design thinkers: Sketch your idea out quickly, before you forget about it. Yet, much beyond seeming trivialities, McKim's studies into exploratory ideation have led him to endeavour comprehensive reflections on, and experimentation with, prototyping materials (Sect. 7.2). After all, different materials and equipment can be more versus less helpful for people to create rapid idea sketches. The sophisticated knowledge design thinkers enjoy today regarding the use and impact of different prototyping materials emerged, in theoretical terms, from McKim's theory of ambidextrous thinking and his studies into (materially facilitated) ideation.

M13) McKim's account of ideation is concerned with individual cognitive processes, which take place during the first recording of ideas, regardless of whether people search for novel solutions alone or in teams.

M14) McKim's concepts of ambidextrous thinking and ideation have furthered extensive knowledge regarding the impact of prototyping materials on cognitive processes—knowledge that design thinkers use in practice up to the present.

6.2 Test and Cycle

The move from idea *E*xpression to *T*esting is characterised by a shift in one's mindset, thinking mode or viewpoint:

> Once you have expressed a number of ideas [...], you are ready to evaluate them. Judgement, deferred in the *E*xpress phase of ETC, is fully exercised in the *T*est phase. Now is the time to be self-critical, not before. [...]
>
> The most crucial imaginative act in the *T*est phase is moving from the viewpoint of creator to the viewpoint of critic. As you view your sketches, imagine yourself in the role of a constructively critical person [...]. (EVT, p. 121)

A55) To facilitate testing, the individual needs to endorse the outlook of a constructive critic and needs to engender critical judgements.

Here, McKim also introduces a treatment of different creative process phases as relating to different mindsets, viewpoints or thinking modes. This outlook is maintained up to the present in design thinking education. For instance, the d.school Bootcamp Bootleg does not speak of "process phases" at all, but of different "modes" during the process.

M15) When present-day design thinking treatises (like d.school Bootcamp Bootleg) address different phases of the creative process as different process "modes," this mirrors McKim's treatment of the topic in EVT. Here, McKim emphasizes how creators need to change their viewpoint/outlook/thinking mode from one process phase to the next.

Methodologically, "testing involves (1) seeing your sketches fully and imaginatively, (2) comparing sketches, (3) evaluating each idea in relation to present criteria, and (4) developing new criteria" (p. 121):

> The first step in the *T*est phase of ETC is to display all of your idea sketches side-by-side. Once displayed, your graphic memory is fully available for the active operations of testing. [...]
>
> Place all your idea sketches on a wall, table, or floor. Step back for an overview. As you view your idea-sketches, attempt to see them as fully and imaginatively as possible, recentering the way you see into a variety of viewpoints. (EVT, p. 121)

Figure 9a shows a visual display as used in architectural practice and education at the time of EVT.

McKim also notes how critical assessments benefit from piece-by-piece presentations of ideas. The recentering that he asks for in the test phase is methodologically facilitated, to a considerable degree, by the grouping and regrouping of ideas in different ways. Thus, McKim's consideration regarding the *T*est phase can be seen as anticipating methods such as "saturate and group" as described in the Bootcamp Bootleg (d.school 2010, Fig. 9b).

Fig. 9 (**a**) Visual displays common around 1970 (image reprinted from EVT, p. 120). (**b**) Visual displays common in present-day design thinking sessions [image reprinted from d.school (2010, p. 14)]

> Physically grouping and regrouping the sketches usually facilitates comparison. Moving your sketches out of the order in which they were expressed and into new juxtapositions also often causes ideas to be seen afresh. (EVT, p. 121)

As an educator and practitioner, McKim immediately considers how equipment and classroom designs can best facilitate the *T*est phase. He comes close to inventing Post-it™ Notes (invented at 3M shortly after the publication of EVT). Certainly McKim's recommendations in EVT created a ready use for sticky notes, once they became available on the market.

> Note how the format of your idea-log influences your ability to compare. A bound notebook makes comparison clumsy; a continuous scroll of sketches prevents side-by-side comparison. Comparison, essential to the act of evaluation, is facilitated by a loose-leaf format that permits you to juxtapose and group [. . .] freely. (EVT, p. 121)

A56) To test ideas, it is helpful to display all available options side-by-side; grouping and re-grouping helps to develop novel views on the material and to develop criteria for evaluation.

A57) Using small, separate paper leafs (like present-day Post-it™ Notes), each depicting just one brief idea, facilitates the process of evaluating large amounts of material; the loose leafs can easily be grouped and regrouped.

Another important objective in the *T*est phase is to deploy criteria in order to evaluate different options. A crucial aspect in this endeavour occurs on a meta-level. *T*esting also means learning which criteria to invoke. What is a worthwhile problem to address? Which needs should the solution address?

> Testing, of course, implies criteria. In the early rounds of ETC, criteria are usually imprecise, incomplete, and implicit. Initial criteria are also frequently inaccurate. The final function of the *T*est phase is to review criteria and to state them more exactly. [. . .] As you formulate and refine your criteria, record them in writing. The revised statement of criteria is an invaluable aid in the next round of ETC. (EVT, p. 121)

A58) The overarching aim of the test phase is to develop an ever better understanding of the criteria that one's solution shall meet (which problem is to be solved with a novel solution and what does the solution need to achieve, in precise terms?).

Recent design thinking practices are closely in line with the objectives McKim describes here as part of the ETC model. Both practices and methodologies evolve in the legacy of the ETC approach.

A good example is the Stanford Design Thinking Virtual Crash Course (d.school 2012), which offers an introduction to design thinking in just 60 min. In pairs of two, participants develop solutions for each other, e.g. to enhance the partner's gift-giving experience. In a first testing round, each participant has about a handful of solutions to test with a partner. The major aim here is not to present seemingly perfect solutions already, but to find better criteria for what should be developed in the first place. Then participants iterate and return to ideation. Now they understand even better what the partner needs, and novel solutions can benefit from this refined set of criteria.

In terms of methodologies, "Design Principles" described in the Bootcamp Bootleg provide a good example of approaches in line with McKim's ETC model. "Design principles" are "statements of criteria" that, according to McKim, should be refined in the *T*est phase.

Here is a description of the method "Design Principles" in the Bootcamp Bootleg:

> You, as the designer, articulate these principles, translating your findings—such as needs and insights—into design directives. These principles give you a format to capture abstracted, but actionable, guidelines for solutions, and communicate your design intentions to others. (d.school 2010, p. 25)

M16) The use of iteration to engender learnings about "what is worth developing" outlined in the ETC model is a core element of design thinking up to the present. McKim wrote about "test criteria" that should be refined over time; in the Bootcamp Bootleg they re-appear in the form of "design principles."

After *T*esting, the next step in the ETC model is to *C*ycle. Thus, people engaged in creative activity can expect to iterate process phases a couple of times before they have developed a solution that seems ready for public release. Notably, each iteration engenders novel learnings, so going back does not mean to start from square one. Moreover, creators shall develop a metacognitive oversight regarding the process. Decisions as to where the project shall continue—how far to move back when iterating?—can be taken in increasingly deliberate ways. Of course, with a longer process model (e.g., from understanding to bringing home) it can be decided in an even more fine-grained way how far creators want to move backwards when they iterate, and to which earlier phase exactly they want to return:

> The first round of idea sketching rarely produces an idea that fully meets your test. After evaluating your first concepts, you are ready to return to idea sketching. At this point, it is often valuable to pause and consider the next strategy you will use in search of a solution. *C*ycling, the third step in ETC, is more than a return to another round of idea expression; it is a return with an idea generating strategy mind. [...] An individual who decides to

> develop one concept in considerable detail has decided on a strategy. Another who opts to generate more ideas before delving into detail with one has decided on another strategy. (EVT, 121f.)

A59) Major aims of cycling in the creative process are to (i) develop an increasingly better understanding of what solution to develop in the first place: criteria for a worthwhile solution (ii) to get better and better at delivering the worthwhile solution and (iii) on a meta-cognitive level, to gain oversight over the creative process, allowing mindful and pointed choices of where to move next, or where to move back, in the creative process.

7 The Importance of Places: Or—Embedded Cognition

In present-day introductions, design thinking is often said to build on three pillars: creative processes, creative people and creative places, the so-called 3 Big P (see Fig. 10). Indeed, few other approaches to the teaching of creativity and innovation include such thorough knowledge about the impact of places on creative performance, and few dedicate as much care to the design of places for the specific purpose of facilitating creativity.

In the history of design thinking, McKim achieved major milestones regarding our theoretical understanding of places. He also introduced many lasting "best practices" in the design of places for purposes of creativity and innovation.

Before McKim, Arnold had already addressed the impact of places in *Creative Engineering*, but his discussion had remained rather brief. Most notably, Arnold discussed (1) place arrangements that help teams maintain high levels of energy in long creative teamwork sessions, and (2) psychological safety as a social condition at workplaces to unleash peoples' creative potential.

To maintain high levels of energy, Arnold had recommended providing . . .

> one less chair than the number of people attending the [creative team] session. This means that one man stands or sits on the edge of a desk or even on the floor. Should any man seated in a chair get up to move around or leave the room for any reason the unseated man quickly takes the vacated chair and so there is a **continual, though imperceptible movement throughout the session, therefore no one becomes physically or mentally fixed**. (Arnold 1959/2016, p. 111, our emphasis)

Like McKim, Arnold had highlighted the impact of body posture and motion on psychological states, including peoples' creative abilities.

Beyond this, Arnold had described social and psychological conditions that need to obtain at the workplace in order for people to be most creative. Ideally, "external standards of evaluation are completely absent. You have **no fear of being thought or being called a fool**" (Arnold 1959/2016, p. 108, our emphasis).

McKim continues to explore the impact of places, and he also seeks solutions that work well in practice. Yet, McKim's account is considerably more comprehensive

Fig. 10 Design thinking builds on three pillars: (knowledge concerning) creative people, creative processes and creative places, the so-called "3 P" [image adapted from D-School (2020) (https://hpi.de/en/school-of-design-thinking/design-thinking/what-is-design-thinking.html)]

and systematic. Most of his suggestions are common practice in design thinking today.

Overall, McKim discusses "places" in a conceptual framework that nowadays would be headlined as "embedded cognition." Here, the idea is that environments are so crucial for the cognitive processes and behaviours of individuals, that it makes no sense to study individuals alone, detached from environments (Clancey 2018). McKim wholeheartedly endorses such a view.

He emphasizes how different tools, such as pen and paper, and people's abilities of using them define to a large extent people's behavioural options and their on-task performance. "Once he has mastered the use of a tool, it becomes almost an extension of his hand" (p. 161). "His knowledge and skill with his tools . . . determines a substantial part of his overall ability" (ibid).

Moreover, actions taken with suitable tools are understood as "enhanced cognitive processes." Thus, McKim speaks of "drawing to extend one's thinking" (p. 10).

> Drawing not only helps to bring vague inner images into focus, it also provides a record of the advancing thought stream. Further, drawing provides a function that memory cannot: the most brilliant imager cannot compare a number of images, side by side in memory, as one can compare a wall of tacked-up idea sketches. (EVT, p. 10)

This is a major purpose, if not *the* most important purpose, McKim provides to explain why people should be drawing. For the most part, during the creative process, drawing does not serve the purpose of communicating fully formed ideas to audiences, but it facilitates the creative thinking process itself.

Moreover, the environment provides strong cues for the individual. For instance, "the materials used are important: inflexible materials tend to cause rigidity in thinking." (p. 40). Thus, environments need to be designed very carefully, in order to provide cues that facilitate intended cognitive processes, such as creative thinking.

Finally, environments shall support the flexibility a creative thinker needs to move between relaxation and energetic attention, between attention directed inward or outward, between phases of single-person pursuits versus teamwork.

7.1 Environments to Facilitate Externalized Thinking

Straightforwardly, McKim encourages thinking by manipulating materials:

> Consider the sculptor who thinks in clay, the chemist who thinks by manipulating three-dimensional molecular models, or the designer who thinks by assembling and rearranging cardboard mockups. Each is thinking by seeing, touching, and moving materials, by externalizing his mental processes in a physical object. (EVT, p. 40)

In present-day terminology, one major advantage of working with physical models instead of mental representations only is that it reduces the load of the working memory. The person does not need to put as much cognitive effort into the maintenance of a mental simulation and therefore has more capacities for other cognitive operations, such as being creative.

Going beyond this, authors like Bamberger and Schön (1983) have argued that in notable cases creative constructions could not occur without tangible form. Conceptions develop in a dynamic interplay of perceiving, reconceiving and doing.

As McKim explains, "externalized thinking involves actively manipulating an actual structure much as one would manipulate that structure mentally" (EVT, p. 40).

The approach of carrying out thinking in the world ("externalized thinking") is often discouraged by conventional education, as McKim says. Thus, students need to re-learn how to facilitate productive thinking by means of working with materials.

> Although you have been educated to do otherwise, link perception, thinking, and action as closely together as you possibly can. Cut; fold; touch; test; hold the pieces together in a new way. Externalize your thinking, as if the process were described accurately by one word, "perceive-think-act." (EVT, p. 40f.)

Notably, the word "perceive-think-act" corresponds to the structure of EVT with its three chapters of seeing-imagining-idea sketching, to explore the realm of visual thinking. Thinking in other modalities, in other representation systems, could be elaborated accordingly.

D22) Externalized thinking means to engage in the triple-activity of "perceive-think-act" at once or in rapid iteration, in order to arrive at novel, worthwhile solutions.

D23) Internalized thinking means to not use "perception" and/or "action" out of the repertoire of "perceive-think-act" in order to arrive at novel, worthwhile solutions.

A60) In the realm of visual thinking, the headline "perceive-think-act" translates to "see-imagine-sketch idea" in the context of creative projects.

When an idea is not only pondered in the mind, but also physically expressed, clearly this has a number of advantages. For instance, the person can take a break and does not have to be afraid of forgetting the idea, as it is captured for later. "Idea sketches are a remarkable extension of imagination, a kind of *visible graphic memory*" (p. 121). McKim also addresses a number of further advantages.

> Externalized thinking has several advantages over internalized thought. First, direct sensory involvement with materials provides sensory nourishment—literally "food for thought." Second, thinking by manipulating an actual structure permits serendipity—the happy accident, the unexpected discovery. Third, thinking in the direct context of sight, touch, and motion engenders a sense of immediacy, actuality, and action. Finally, the externalized thought structure provides an object for critical contemplation as well as a visible form that can be shared with a colleague or even mutually formulated. (EVT, p. 40)

A61) Artefacts created in the course of externalized thinking can be created in any medium or representation system and are typically created intentionally.

A62) Compared to internalized thinking, externalized thinking has a number of advantages: it provides memory aids, both short-term and long-term; it nourishes thinking with sensory details; it promotes serendipitous discoveries; it reveals opportunities for action; it facilitates the critical assessment of an idea; it helps to compare different solutions side-by-side; it enables communicating ideas to others—shared artefacts are a vital means for co-creation of ideas in teams.

Naturally, this concept of externalized thinking encourages a corpus of theorising and practices concerning prototyping materials.

7.2 Prototyping Materials and Space-Design

In remarkable detail, McKim considers the advantages and disadvantages of various materials that can be used for prototyping, or "rapid visualization" by the time of EVT. Overall, he recommends easy-to-use materials:

> Materials that involve the visualizer in difficult techniques [...] will absorb his energy and divert his attention away from thinking. Time-consuming techniques also impede rapid ideation, since ideas frequently come more quickly than they can be recorded. [...] The best materials for visual thinking are direct, quick, and easy to use. (EVT, p. 30)

A63) Prototyping materials to facilitate ideation need to be (i) so easy to use that creators can devote all their voluntary attention to idea generation (instead of being distracted by difficulties of the prototyping process), and (ii) they need to be so quick that creators can express their ideas before forgetting about them, even when ideas emerge rapidly one after the other.

McKim also recommends using inexpensive materials: "From the wide variety of papers available, the less expensive is advised, especially for the beginner. Costly paper tends to inhibit thinking" (p. 31).

A64) Prototyping materials impact the creative thinking process (e.g., expensive paper inhibits thinking; rigid materials lead to rigid thinking).

McKim considers a number of materials with their relative advantages and disadvantages, such as the following:

> Clay, the traditional sketch material of the sculptor, has many disadvantages to weigh against its basic advantage of malleability. Clay's soft plasticity tends to limit, and even to define, the kinds of forms that can be visualized; it directs ideation to surface considerations; it is heavy, messy, and time-consuming. Styrofoam is an important alternative to clay: it is relatively stiff, can be easily formed into a hollow structure, and can be glued. (EVT, p. 31)

Based on such considerations, McKim provides material lists to help equip environments for creative thinking.

Notably, there is a strong continuity between McKim's considerations and suggestions formulated by Schools of Design Thinking today. Thus, the d.school (2011) also provides a materials list to help equip design thinking environments, and it strongly resembles McKim's original compilation. Figure 11 provides a side-by-side comparison.

Beyond basic prototyping materials, McKim also recommends using technical equipment in the creative thinking process: "In addition to the inexpensive materials so far listed and described, the visual thinker should consider acquiring optical equipment to be used as tools for visual thinking" (EVT, p. 31). Thus, for instance, he recommends "**cameras**, useful for making 'record shots'" (ibid., our emphasis). Again, the continuity to present-day design thinking equipment is obvious. Figure 12 depicts methods in the design thinking Bootcamp Bootleg (d.school 2010), which also invoke cameras for making record shots.

McKim also advises: "**Organized storage** should be provided close to each work area to diminish distracting clutter." (EVT, p. 31, our emphasis). Today, the Schools of Design Thinking standardly offer such storage (Fig. 13).

Moreover, McKim reflects on work surfaces. Of course, paper can be placed on tables, horizontally. McKim also emphasizes that vertical surfaces can and should be used for capturing ideas:

> To alleviate back tension, and also to provide for the important element of change, a **stand-up, vertical drawing surface** should be available: a blackboard, easel, or wall-mounted roll of paper. (EVT, p. 31, our emphasis)

A65) Providing work areas with horizontal and vertical planes (e.g., tables and whiteboards) encourages motion and change; it also helps to maintain body states that facilitate energetic work over long workdays (e.g., no back pain).

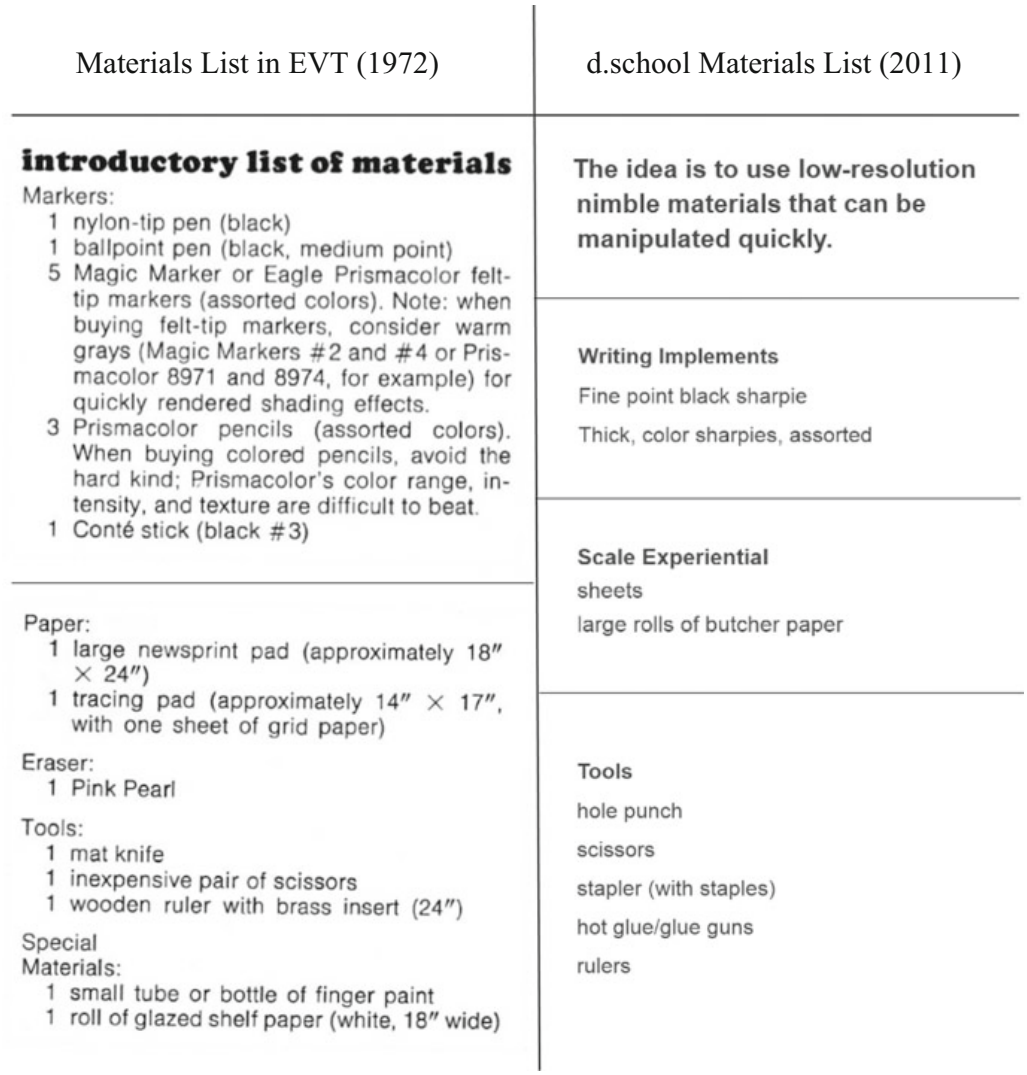

Fig. 11 Ever since EVT, it is common practice in design thinking to discuss equipment in support of the creative thinking process, especially to facilitate rapid prototyping. Left: excerpts of a materials list compiled by McKim in EVT. Right: Excerpts of a materials list compiled by the d.school (2011)

Once again, such vertical surfaces are now to be found everywhere at the Schools of Design Thinking, as an alternative to working on tables (Fig. 14).

McKim also concerns himself with suitable arrangements for groups, so that all team members can engage equally in group activities:

> It can be easily demonstrated, for example, that five people sitting in a straight line cannot interact verbally as well as can five people sitting in a circle. [. . .] Clearly, **an inter-active group needs to be able to work over a shared visual image**, suggesting modifications, and changes, making erasures, and so on. (EVT, p. 32)

Fig. 12 In line with recommendations in EVT, design thinkers at present still use cameras for making record shots in the creative process [images reprinted from d.school (2010, pp. 8 and 42)]

Fig. 13 As recommended in EVT, environments for design thinking still provide organized storage for prototyping materials close to work areas (photo from the HPI D-School)

Fig. 14 Stand-up, vertical drawing surfaces are a characteristic element of design thinking environments today, in continuity with EVT suggestions (photo from the HPI D-School)

A66) In teamwork, furniture and spatial arrangements should court the team to form a circle; everyone needs to have good access in terms of sight and touch to the team's work area.

In the passage above, McKim reflects on group activities that involve sketches. In some other cases, drawing may not be the best approach for teams to jointly visualise and develop ideas. Sometimes, it can be more favourable to work with three-dimensional models. A respective example discussed by McKim concerns Nobel Laureate James D. Watson and his colleagues, who worked on the structure of the DNA molecule. "A complex structure such as the DNA molecule is difficult to visualize in imagination or on paper" (EVT, p. 8). Instead, "Watson and his colleagues visualized this complex structure by interacting directly with a large three-dimensional model" (EVT, p. 8).

Thus, environments for creative activity also need to facilitate joint model building.

A67) To facilitate creative work, environments needs to support both 2-dimensional visualizations and 3-dimensional model building, all from rough to refined.

Fig. 15 A design thinking team today, engaged in externalized thinking by means of rapid prototyping. The design thinking environment, which facilitates the activity, resembles spatial setups suggested in EVT for creative teamwork (photo from the HPI School)

Figure 15 shows a group of design thinkers acting much as McKim suggested: Standing not in a line, but rather in a circle around a table, where they can all jointly see and develop ideas by means of rapid prototyping, using externalized thought and a bias to action. Thus, they are engaged in an inseparable synthesis of "perceive-think-act" (EVT, p. 41).

M17) From considerations regarding different prototyping materials, over optical equipment (such as cameras) and organizing storage to horizontal versus vertical work planes—McKim has provided ample recommendations for the design of creative places that design thinking environments use up to the present day.

7.3 Facilitating Flexibility with Spatial Designs

While much of a creative project consists in energetic work, McKim generally emphasises the importance of flexibility. This notably includes flexible shifts between work phases at high levels of energy versus phases of dedicated relaxation (cf. Sect. 4.1). He emphasises how environments for creative work need to facilitate

Fig. 16 EVT highlights the importance of designing environments where people can shift, flexibly, between active creative work versus relaxation. Correspondingly, environments for design thinking typically include cosy corners, as the one shown here, where design thinkers can retreat and relax (photo from the HPI D-School)

this kind of flexibility. "The visual thinker should also have access to **a quiet place where he can relax** and turn his thoughts inward—or stop thinking entirely: a reclining chair, a couch, or even a relaxing bath" (EVT, p. 32, our emphasis).

A68) Environments for creative work need to facilitate flexible shifts between phases of (i) active, energetic concentrated work on a task and (ii) relaxation.

Again, present-day design thinking environments are carefully constructed to facilitate this kind of flexibility. While at Stanford even a room has been designed to look and feel like a sauna for people to retreat, at the D-School in Potsdam several cosy corners are provided. Some offer huge couches in protected areas where individuals can even take a nap, others offer an easy chair (as in Fig. 16).

To recall, the overarching aim of EVT is to train flexibility. "A major purpose of this book is to encourage a [. . .] universal condition that fosters productive thinking: flexibility" (EVT, p. 2). Consequently, also in his discussion of environments for creative work, McKim emphasises the importance of flexibility. Spatial arrangements should not be static, and they should not be the same for everyone. Environments for creative activity need to be changeable, so that people using the space can adapt it to their preferences and purposes. Environments need to help people become as flexible as possible, and creative individuals need to develop a habit of actively establishing environments conductive to their pursuits. In this context, McKim also emphasises how individuals can react differently to

environments. Each person needs to develop an individual sensitivity towards how the room affects him or her:

> The visual thinker should also consider the subjective nature of his environment. [. . .] The visual thinker who is emotionally comfortable in and stimulated by the [. . .] character of his environment [. . .] will be more productive than the visual thinker who is rubbed wrong by his surroundings. (EVT, p. 32)

Once again, McKim invokes a historical and biographical approach to emphasise how important it is for creators to be mindful of the environment, and to self-create environments that are conductive to one's projects:

> Dr Johnson needed to have a purring cat, orange peel, and plenty of tea to drink . . . Zola pulled down the blinds at midday because he found more stimulus for his thought in artificial light. Carlyle was forever trying to construct a soundproof room, while Proust achieved one. Schiller seems to have depended on the smell of decomposing apples which he habitually kept concealed in his desk. (EVT, McKim quoting McKellar, p. 32)

A69) Expert creators have developed a high degree of sensitivity towards how the immediate environment impacts their creative processes; they actively seek out favourable environments and re-design spaces, so as to render them most conductive towards their own creative processes.

These concerns for flexibility in spatial designs have been pursued and elaborated ever since EVT. In their comprehensive compendium on spatial designs for creative work, Doorley and Witthoft (2012) emphasize as one principle: "Make a flexible space. Create a space that adapts to the needs of the people who use it" (p. 270). Moreover, as Leifer and Steinert (2011) point out, innovation is generally about making changes, and "space has emerged as a key factor to facilitate change" (p. 156). In order for spaces to facilitate innovation, aka change, innovation spaces need to be flexible themselves: "The key concept for the spatial setup is flexibility (adaptive/agile work places)" (p. 156).

Beyond McKim's original suggestions for spatial designs in EVT, the concern for flexibility has been pursued even further. Nowadays, design thinking spaces even involve mobile walls and furniture on wheels, so as to provide the greatest possible flexibility for people to redesign rooms on the fly, according to need.

> The key concepts [for space-design] include:
> – Use flexible room separators instead of fixed walls [. . .]
> – All furniture is easily movable and modular to serve multiple, often previously unexpected purposes. (Leifer and Steinert 2011, p. 156f.)

Moreover, design thinking research has found that experienced design thinkers indeed adapt and change their work environment much more regularly than design thinking novices (Weinberg et al. 2014). In an observational study, teams of design thinking beginners set up their work spaces in the beginning. Then, with only one exception, "the initial spatial setting remained untouched for the duration of the innovation project, although all furniture was easy to move" (Weinberg et al. 2014, p. 915).

Thus, design thinking novices do not exhibit flexibility in their own environmental designs. One spatial setup is rigidly maintained. This contrasts to design thinking experts.

> Teams [of design thinking experts] divided their workspace into two separate parts [...]. During their teamwork sessions the teams switched frequently between two or more spatial settings [...]. Working on analysis and synthesis was quite [often] done at the high table while sitting on high chairs or standing in front of the whiteboard. Brainstorming and ideation was most often done either sitting or standing in front of one or two whiteboards. For team reflection the teams preferred to use the circular sitting area. (Weinberg et al. 2014, p. 916f.)

In this study, design thinking experts demonstrate awareness for the need discussed by McKim to shift flexibly between different work modes, such as highly concentrated work at the whiteboards versus more relaxed moments of team reflection. As encouraged by McKim in EVT, these different work modes are supported by corresponding, suitable changes in the environment.

McKim's biographical approach also highlights the initiatives of well-known creators, who redesign their environments so as to better address their own needs. Similar initiatives are observed among design thinking experts in the study by Weinberg and colleagues.

> In contrast to the design thinking beginner's teams the design thinking expert teams used individual artefacts to 'decorate' their team space. These items fall into two categories: individual decorating items (e.g. plants and a carpet) and items intentionally brought in by team members related to their innovation challenge [...]. (Weinberg et al. 2014, p. 916)

Thus, design thinking experts appear to make changes in the work environment mindfully, so as to facilitate each and every phase of the creative process with dedicated spatial setups, very much in line with McKim's suggestions in EVT (Fig. 17).

Fig. 17 Experienced design thinking teams adjust their work spaces regularly to changing needs in the course of different creative process phases. Differing spatial setups are invoked for concentrated work phases as opposed to moments of relaxation and reflection [images reprinted with permission from Weinberg et al. (2014)]

Overall, McKim's *Experiences in Visual Thinking* has provided a cornucopia of theoretical frameworks and practices, which have been formative for design thinking as a unique approach to creativity and innovation.

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