representative of a universal basic-level category. Of course, in a design project, this might be difficult to achieve, and designers, researchers, and businesses might need (or want) to aim for characteristics that are shared in a specific group of cultures. However, if a typical representative of a universal basic-level category were achieved, I suggest, the content might be universally and intuitively comprehensible. Furthermore, it might be permanently comprehensible, too, because the physical world and its flora and fauna might not change significantly in the next few thousand years. This brings me to the final design guideline for universal, intuitive, and permanent pictogram contents:

G34: Represent typical basic-level contents.

The Pictogram Design Production Process

In Step 3, I have developed an approach to the reference relation, I have presented the UIPP meanings prescribed by the UCUI project, and I have derived and evaluated content candidates for the UIP Pictograms. In Step 4, so far, I have developed an approach to the design relation, and I have presented guidelines for the design of pictogram contents. In the following section, I describe the design production process in which the previous results were applied.

The UIPP Design Production Process as a Research Through Design Project

As described in Section *The UIPP Design Process and the Chapters of this Book* (p. 26), UIPP performs a complete human-centered design process for universal, intuitive, and permanent pictograms. Regarding HCD processes, two main problems need close consideration. First, there is still a lack of studies that go "the full cycle of a human-centred design process. In particular, the transition from requirements to design solutions has been identified as a problem for design" (Hurtienne et al. 2015, pp. 239–240) [204]. That is, studies on human-centered design do not explain "how a designer transforms the information gathered about users and their work into an

effective user interface design" (Wood 1998, p. 10) [438]. In other words, they do not close the design gap (see Section *Universal, Intuitive, and Permanent Pictogram Project: Two Main Goals*, p. 21). As a result, it is not clearly understood how designers proceed, and how they achieve their results. Second, since it is not clearly understood how designers proceed, their production process cannot be integrated optimally in the HCD process (e.g., Cash 2018 [75], Zimmerman et al. 2007 [447]). For example, it remains unclear how strictly designers should adhere to scientific findings (Hurtienne 2017, pp. 15–16) [196]. This is a problem because the work of experienced designers is still superior to, for example, the results of mathematically described approaches (e.g., Cole et al. 2009, pp. 8–9 [93], Sayim and Cavanagh 2011, p. 3 [371]), thus, the work of designers cannot be substituted (Hurtienne 2017, p. 15) [196].

UIPP addresses these problems by using a research through design (RTD) approach to the pictogram design production process. In the following, I describe the approach. Famously, Frayling (1993, p. 5) [140] distinguished between research *into* art and design, research *for* art and design, and research *through* art and design. Almost at the same time, Archer (1995, p. 11) [16] addressed the same categories as research *about* practice, research *for the purposes* of practice, and research *through* practice[5]. Frayling and Archer defined the first category, that is, research into design practice, as the historical, social, economic, material, or perceptual research concerning design and its products. The second category, research for design, is defined as the activity of collecting material "where the end product is an artefact – where the thinking is, so to speak, *embodied in the artefact*" (Frayling 1993, p. 5) [140]. In that category, research is not

[5] Archer has coined the phrase as early as in 1981, according to Findeli et al. (2008, p. 71) [133].

realized in written or spoken language but as a visual, tangible, or multimodal product. Although the activity of research for design might be scientific, the realization of the product should not be considered research, according to Archer (1995, p. 11) [16]. However, today, gathering and interpreting scientific findings and user studies are considered research for design, too (Stappers and Giaccardi 2017) [390]. Third, research through design is a practical process of experimentation. Archer (1995) [16] said that "[t]here are circumstances where the best or only way to shed light on a proposition, a principle, a material, a process or a function is to attempt to construct something, or to enact something, calculated to explore, embody or test it" (p. 11). Consequently, research through design is a production process. This process is situation-specific, that is, it "is pursued through action in and on the real world, in all its complexity, its findings only reliably apply to the place, time, persons and circumstances in which that action took place" (Archer 1995, p. 12) [16]. The result of that process is an artifact, for example, a metal object or the customization of a given technology. Although the results are generalizable only to a small degree, they "can advance practice and can provide material for the conduct of later, more generalisable, studies" (p. 12). Research through design occurs frequently in disciplines with a strong practical focus, and it is based on the practitioner's tacit knowledge.

Since these early definitions, RTD has developed into an independent research approach and, at the same time, an attempt to integrate design practice into more scientific disciplines, for example, HCI (Zimmerman et al. 2007, p. 493) [447]. RTD addresses the abovementioned two problems of HCD processes by reflecting on the designer, the production process, and the best use of the skills of designers. In addition, it generates innovative artifacts that embody theory and technical possibilities allowing for new ways of interaction (Gaver 2012, pp. 941–942 [144], Stappers and Giaccardi 2017 [390], Zimmerman et al. 2007, p. 498 [447]).

The UIPP design production process was structured as a RTD project. In that, Findeli's project-grounded model was followed (Findeli 2010) [132]. Findeli's approach has already been used successfully in other RTD projects (see., e.g., Hemmert 2014 [178]). In contrast to Frayling and Archer, Findeli does not distinguish between research for and research through design. He says that RTD "must be understood as having the virtues of *both*" (Findeli et al. 2008, p. 71) [133]. According to Findeli, "the central distinction that needs to be made is between a research question and a design question" (Findeli 2010, p. 294) [132]. Design projects often start with a design question. Then, the initial step is to create a research question from the design question. The second step consist in the creation of a design answer, considering the design project the field of research. Finally, the design answer will contribute to the research answer. Findeli calls his approach project-grounded research and argues that it can contribute to the knowledge of any phenomenon (Findeli 2010, p. 299) [132]. In UIPP, the design question was the question, how to design universal, intuitive, and permanent pictograms. Following Findeli's model, the steps in the design production process were considered the research questions. These steps were planed according to ISO 9241:210 (see Section *The UIPP Design Process and the Chapters of this Book*, p. 26). In each step, the research questions were answered through design. Consequently, the produced design prototypes were considered the design answers. Subsequently, the design answers were transformed into research answers by evaluating the interaction of the users with the pictogram prototypes in Step 5 (Findeli 2010, p. 289) [132].

Approaching the Research Questions: the HCD Production Process

The production of design prototypes is Step 4 in a human-centered design process. ISO 9241:210 suggests several intermediate steps for the process. In Table 14, I describe the intermediate steps (iSteps) according to that framework. Furthermore, ISO 9241:210

recommends taking other design methods and principles into account. Consequently, I describe established methods and guidelines that were used in the UIPP process to specify further and give reasons for each step. In addition, I describe the practical approach in the IBIS project (in German: Gestaltung intuitiver Benutzung mit Image Schemata) which I consider a best-practice example of a complete human-centered design process that uses the theory of embodied cognition for the production of intuitive user interface prototypes (Fetzer et al. 2013 [131], Löffler et al. 2013 [271], Löffler et al. 2013 [272]).

Table 14

Intermediate steps (iSteps) 1–4 in the design production process according to HCD

Intermediate step number and title Source	Content
iStep 1.1: Specification of context of use and user requirements	
ISO 9241:210	ISO 9241:210 defines the context of use as the "users, tasks, equipment (…), and the physical and social environments in which a product is used" (International Organization for Standardization 2010, p. 2) [211]. The understanding of the context of use, the users, their requirements, and the user tasks are considered the first intermediate step in the production process. According to ISO 9241:210, the production process relies on them (International Organization for Standardization 2010, p. 15) [211]. Furthermore, the understanding achieved in this intermediate step must be transferred to the production process and communicated to the people that are involved in the process.
Hartson and Pyla, Sharp et al., Shneiderman et al.	Shneiderman et al. (2017, 133-134) [382], Hartson and Pyla (2012, pp. 161–180) [172], and Sharp et al. (2019, pp. 41–49) [380] described the process similarly to ISO 9241:210.
iStep 1.2: Planning tasks and interaction between user and system	
ISO 9241:210	The first intermediate step also includes the planning of the design that will be produced in the process. Furthermore, decisions are made, how the design will be approached in order to fulfill the previously described user requirements with regard to the context of use and the tasks that need to be carried out. Individual design tasks are identified. ISO 9241:210 states that "decisions at this point can include issues such as the choice of modality (e.g. auditory, visual and tactile) and the choice of media (e.g. text versus graphics, dialogue boxes versus

	wizards, mechanical versus electronic controls)" (International Organization for Standardization 2010, p. 15) [211]. The order in which the tasks are completed can be changed, according to the design process.
Sharp et al.	Sharp et al. (2019, pp. 434–445) [380] called this step conceptual design. They said, it focuses on the development of a conceptual model of the design solution.
IBIS	In IBIS, it was noted that it is important to decide at the beginning of the production process which one of the image schematic metaphors should be produced as a prototype (Löffler et al. 2013, p. 39) [272]. IBIS' image schematic approach is similar to UIPP's approach.
iStep 1.3: Reviewing state of the art solutions and guidelines	
ISO 9214:210	ISO 9241:210 states that the team members should look at "the established state of the art in the application domain, design and usability guidelines and standards" (International Organization for Standardization 2010, p. 14) [211] in the beginning of the production process.
iStep 2.1: Production of design solutions	
ISO 9214:210	The second intermediate step is the production of designs, using the specification, reviews, and plans made in Intermediate Step 1. Here, the designs are made "more concrete (for example making use of scenarios, simulations, prototypes or mock-ups)" (International Organization for Standardization 2010, pp. 15–16) [211], thus, allowing explicit interaction with the proposed design products and subsequent discussion. It is advised to produce several designs.
Cooper et al., Macbeth et al., Nielsen, Sharp et al., Shneiderman et al.	Sharp et al. (2019, pp. 445–446) [380] called this step concrete design. Cooper et al. (2014, p. 37) [94] said that it should start with a kickoff meeting in which the product is discussed, and the stakeholders and designers are introduced. There are various methods for the production of designs. Two options are focus groups and production groups. In focus group design, a group of participants generates ideas, and each participant creates a design. Then, the group decides which design solution is the best. In production group design, participants create independently designs. Then, a designer evaluates the designs and creates a final design solution from these designs. Macbeth et al. (2000, p. 329) [278] found that focus groups yield better results. Nielsen (1993, pp. 86–87) [320] recommended parallel design as a design method. In a parallel design process, multiple designers work independently on the same project at the same time in order to produce distinct options that can be compared, discussed, and refined subsequently. Shneiderman et al. (2017, pp. 142–144) [382] described yet another method: ideation and creativity also called convergent thinking. This approach includes the continuous specification of possible designs. Shneiderman et al. (2017) [382]

	considered it suitable for teams of designers "who each bring their own expertise and visions to the table" (p. 143).
IBIS	In IBIS, it was recommended to create a project plan during the kickoff meeting (Löffler, Heß, Maier, & Schmitt, 2013, p. 40). Furthermore, nine roles are described that are involved in the design process with the intention to allow for a quick understanding of the skills that are needed for specific activities. Not all roles are always needed for a design process, and one person can take over multiple roles. Here, I only describe the roles that are involved in the UIPP production process: The requirements engineer gives information on the technical system requirements; the theory expert (IBIS called this role image schema expert) knows the theoretical background and must be able to revise the design solutions with regard to the theory; the designer develops ideas and creates prototypes from these ideas; and the developer implements the prototypes (Löffler et al. 2013, p. 7) [271].
iStep 2.2: Producing prototypes	
ISO 9214:210	ISO 9241:210 recommends creating prototypes in iStep 2. Prototypes are simplified and limited design products that allow exploring "alternative design solutions. While there can be substantial benefit in making the design solutions as realistic as possible, the level of detail and realism should be appropriate to the issues that need to be investigated. Investing too much time or money in producing a detailed working prototype can lead to a reluctance to change the design" (International Organization for Standardization 2010, p. 16) [211].
Hartson and Pyla, Hemmert, MacKenzie, Nielsen	Nielsen (1993, pp. 93–99) [320] recommended prototyping, too, because intermediate evaluation and subsequent refinement are only possible with produced prototypes, not through abstract discussions and guidelines. In addition, it is fast and less costly to work with prototypes. Hemmert (2014, p. 68) [178] considered prototypes the central object in the design process. One suitable form of prototype is the paper mock-up, that is, drawings or printouts of digital, on-screen designs (see Hartson and Pyla 2012, pp. 391–425 [172] and MacKenzie 2013, pp. 128–129 [279], too).
IBIS	In IBIS, sketches were drawn (Löffler et al. 2013, p. 55) [272].
iStep 3: Iteration	
ISO 9241:210	Intermediate Step 3, according to ISO 9241:2010, is the continuous refinement of the designed prototypes. Refinement can be achieved through iterative evaluations. Reiterations are useful because human-computer interactions are complex and can hardly be specified in their entirety at the beginning of a development process. Many requirements will emerge only during the process. In each iteration, the prototype must be evaluated, and feedback must be given which is integrated subsequently through an alteration of the prototype. The

	alteration should be evaluated, too. Furthermore, "[p]roject plans should allow sufficient time for making the changes as a result of such feedback" (International Organization for Standardization 2010, p. 16) [211].
Nielsen	Nielsen (1993, pp. 105–109) [320] recommended iterative design, too, and gave practical examples. He suggested that a detailed evaluation of the solutions might not be feasible in each iteration, but iterations are fruitful even if they are exclusively an occasion for trying out the prototypes in different settings. For each iteration, he recommends making design decisions explicit and documenting the reasons for the decisions.
IBIS	In IBIS, the drawn sketches were continuously developed and refined into production prototypes (Löffler et al. 2013, p. 55) [272]. They called one step is in this process "MetaphernCheck" (Löffler et al. 2013, p. 40) [272]. This step specifically addressed the evaluation of the suitability of the designed image-schematic content, that is, whether the prototypes convey the intended meanings.
iStep 4: Communicating the design products for implementation	
ISO 9241:210	The final intermediate step in the design production process is the adequate communication of the design products to the team that is responsible for the implementation of the designs. ISO 9241:210 states that the most appropriate means for communicating the results "vary from providing appropriate documentation, to producing revised prototypes, to embedding experts in human-centred design in the design and development team" (International Organization for Standardization 2010, p. 16) [211].

Presentation of the UIPP Design Team

Cooper et al. (2014, pp. 146–147) [94] recommended small expert teams that focus on a specific task for the design production process. Consequently, the UIPP design team consisted of three designers, each holding a university degree in design. Two designers were experts not only in pictogram design but also in interaction design. Both worked for a design agency, one of them coleading the agency. Both designers were remunerated through the UCUI project. The third designer was the author of this book. According to Findeli et al. (2008, pp. 76–80) [133], the design team should be multidisciplinary. ISO 9241:210 adds that the team does "not have to be large, but the team should be sufficiently diverse to collaborate over design and implementation

trade-off decisions at appropriate times" (International Organization for Standardization 2010, p. 8) [211]. The team should include people with various skills and disciplinary backgrounds, for example, in human-computer interaction, user interface design, user research, technical support, and software engineering. All those skills and backgrounds were found in the UIPP design team. In addition, scholarship in semiotics and the cognitive sciences was brought into the team by the author of this book.

Technical Constraints by UCUI

In addition to the guidelines presented in Section *Guidelines for Designing Universal, Intuitive, and Permanent Pictogram Contents* (p. 207), technical constraints for pictogram design were set by the UCUI interface prototype (see Section *Universal, Intuitive, and Permanent Pictogram Project: Two Main Goals*, p. 21). These constraints are not universal, but they were requirements for the UIPP production process, in addition to the requirements derived in the previous steps. For that reason, they are presented in the following (M. Huber, personal communication, August 9–10, 2018):

- Pictograms should have 125 x 125 px and 120 dpi.
- Files should have SVG format. However, PNG and GIF is possible.
- Pictograms should be black and white, or they should have more than two colors.
- Several pictograms can be displayed at the same then, however, then, pixels must be reduced accordingly.
- Up to 3 animations are possible at the same time.
- Animation speed can be set from 0.1 s to 25.4 s.

Design Answers: Report of the UIPP Design Production Process

In general, it is agreed that the documentation of a RTD process is central to the RTD

approach (e.g., Hemmert 2014, pp. 66–67 [178], Zimmerman et al. 2010, p. 316 [448]). The actions and the reasons for the actions, that is, the design rationale, should be documented in order for designers and researchers to be able to reproduce them. This holds although "there is no expectation that others following the same process would produce the same or even a similar final artifact" (Zimmerman and Forlizzi 2014, p. 168) [446]. In Table 15 (p. 244), I report the UIPP design production process. I do so by presenting the procedure of the UIPP design team. That is, I describe the designers' meetings, plans, and ways to approach the previously described intermediate steps in the production process in order to produce design answers to the RTD research questions. In addition, for each step, I report the designers' findings and decisions based on their practical experience, tacit knowledge, and skills.

Table 15

Report of the UIPP design production process

Phase Date iSteps	Content
kickoff meeting January 24, 2018 1 hr iStep 2.1	The design production process started with an early kickoff meeting (iStep 2.1). For this meeting, the UIPP design production team came together for the first time. The team members were introduced. Prior to the meeting, the two designers working for the design agency received a paper that explained the UIPP project. During the meeting, the agency's designers asked further questions regarding details and goals of the project. A production process plan was developed which is presented in Figure 29:

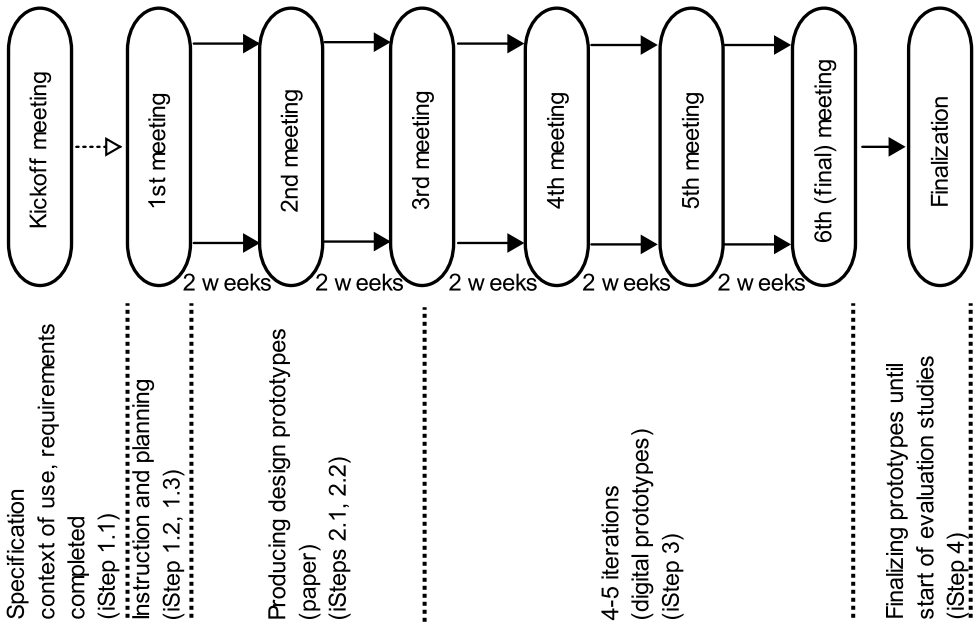

Figure 29. UIPP design production process plan.

	The following roles were to be involved in the process, according to the plan: requirements engineer (prior to the production process), theory expert, designer, and developer (after the production process).
Decisions and findings	In the meeting, it was decided that the production process would start after the completion of the derivation of the pictogram contents and of the design guidelines. The kickoff meeting took place during Study 2.
1st meeting August 14, 2018 2 hr iSteps 1.1, 1.2, 1.3	In UIPP, examining suitable theories, specifying visual representation, and deriving content candidates as much as the guidelines for content design are considered the specification of the context of use and the user requirements (iStep 1.1). These intermediate steps were completed prior to the design production process. Consequently, the design team was briefed about the results in writing prior to the beginning of the production process. Established pictograms were reviewed at the beginning of the first meeting (iStep 1.3). See Figure 30 (p. 246) for an example of the presentation of established pictograms. The design team discussed approaches to the design of the pictograms (iStep 1.2), and it discussed the further organization of the production process.

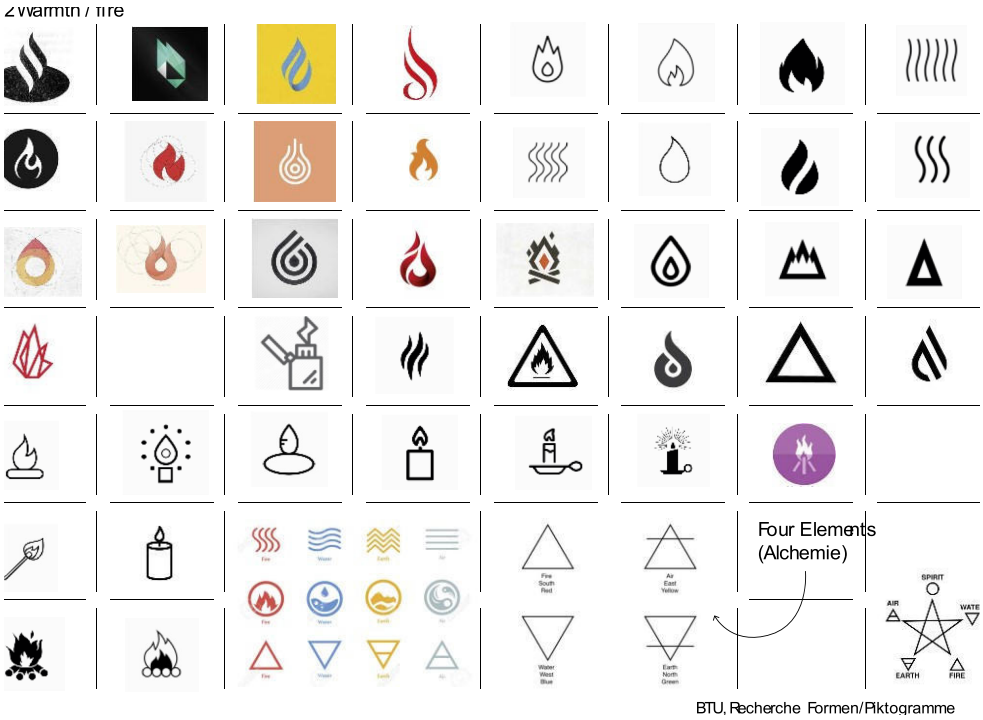

Figure 30. Presentation of established pictograms for the meaning *warmth*.

Decisions and findings	It was decided that a parallel design method would be used to produce the design prototypes. Furthermore, it was decided that the team would start with a small set of pictograms and not tackle all pictograms at the same time in order to prevent confusion. It was found that the design system could not be developed independently from the pictogram prototypes. Consequently, the design system should be specified as a result of the process. In the discussion, the established pictograms were considered highly abstract and conventional (see Section *Conceptualizing the Relations of Design and of Reference*, p. 41). Following the content taxonomy that was developed in Study 1 (*Results*, p. 135), It was decided that two groups of UIPP pictograms were needed. On the one hand, pictograms that represent a content and, on the other hand, pictograms that represent a content through another content. The first group was called simple, the second group was called compound (see Section *Presentation of the Design System and of the Pictogram Prototypes*, p. 255).
2nd meeting planned: August 29, 2018 took place: August 22, 2018 2 hr iSteps 1.3, 2.1, 2.2	Following the parallel design method, the designers worked independently on their designs between each meeting (iStep 2.1). Furthermore, they chose independently the pictogram contents for their designs (iStep 1.3). Sketches were drawn (see Figure 31, p. 247), and the first digital prototypes were designed (iStep 2.2). The designers were motivated by the project goals and worked faster than planned. As a result, they met one week earlier. During the meeting, the designs were presented, discussed, and each designer gave feedback. Furthermore, the chosen pictogram contents were discussed. At this point, the designed prototypes were still rather abstract

and similar to established pictograms. It was emphasized that the pictograms should be designed according to the UIPP design guidelines—not imitating established designs. Real-world objects and actions should be represented as pictogram contents, not conventional signs, for example, pictorial runes that can be found in comics (Forceville 2011) [134]. In the end of the meeting, the next steps and design options were determined (iStep 2.1).

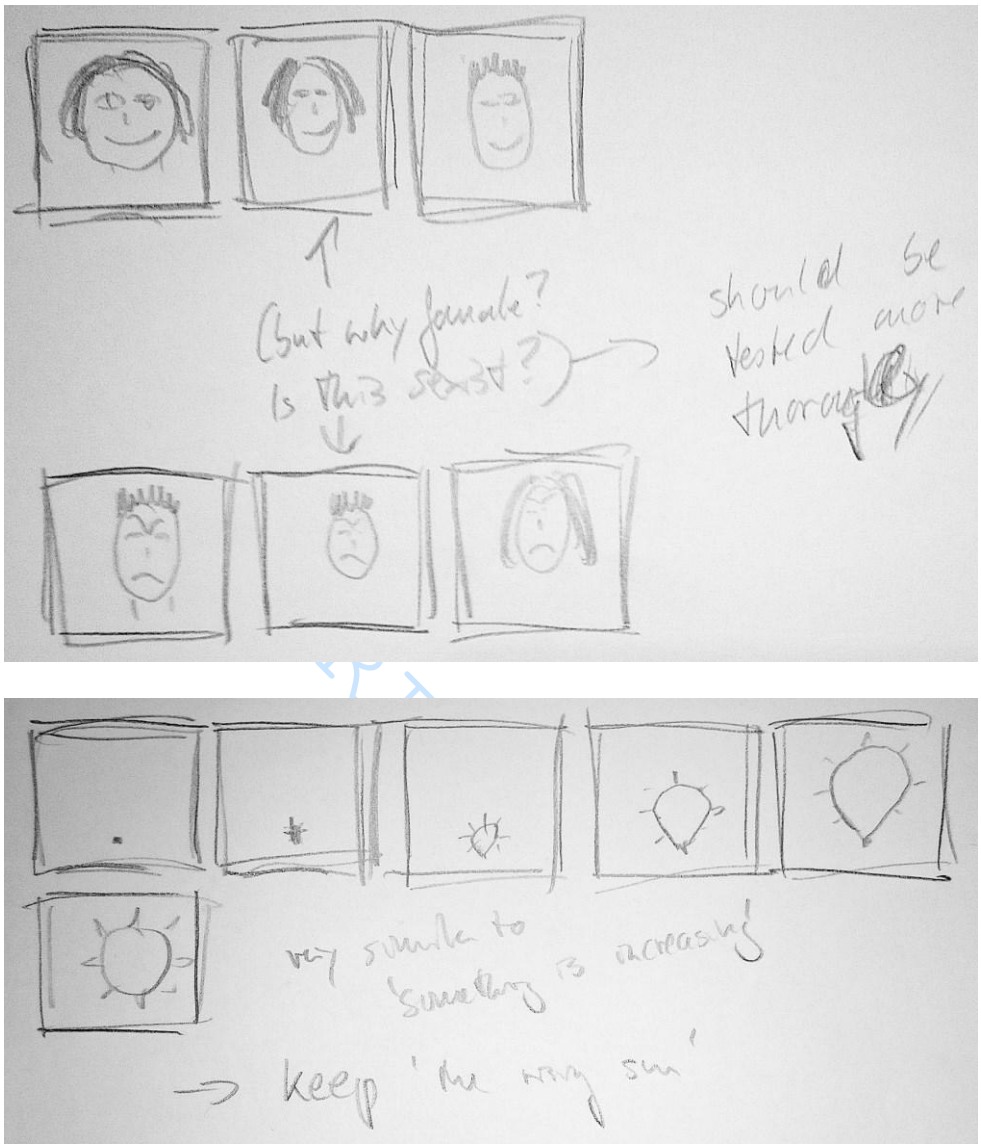

Figure 31. Examples of sketches drawn for the meanings *[something] is good, positive*, *[something] is bad, negative*, and *[something] begins*.

Decisions and findings

The designers decided independently from each other which of the pictogram contents that were derived and ranked in Studies 1 and 2 they considered most suitable for the prototypes. However, they discussed together whether the contents *a big, muscular man* or *a male arm with*

	flexing biceps might be less suitable for the meaning *power* in the context of use of a heating system user interface than the content *lightning bolt*. The subject arose because, in Study 1, contents were derived without informing participants about a specific context of use. The designers decided to use the content *a male arm with flexing biceps* in order to aim for universal use of the pictograms. It was considered difficult by the designers to ignore the established pictogram designs because the designers were very familiar with them. As a consequence, they used the familiar designs intuitively instead of adhering to the UIPP guidelines. Several properties of pictogram contents were discussed, for example, whether representing the face of a smiling girl for the meaning *[something] is good, positive* is sexist, despite the fact that the content was derived in Study 1 (see Figure 31, p. 247). Furthermore, it was discussed that a fire might not be a suitable pictogram content for the meaning *warmth* because fire might suggest danger. It was determined that a pleasant and harmless fire should be represented, for example, a campfire. The content *piece by piece [something] is taken away* was not considered suitable because it suggested the interpretation of *[something] is disappearing* when represented visually. Finally, it was discussed that compound pictograms such as *[something] begins* or *[something] is everywhere* require to represent their content as being currently in a process in order to be able to convey the intended meaning. Take the example *[warmth] begins*. The content of the pictogram *[something] begins* is *a baby being born* or *the rising sun*. It was found that not birth or sun should be represented as the content. Instead, the beginning of warmth must be represented through the representation of *warmth* as being in the process of being born, like a baby, or as being in the process of rising, like a sun. This applies to all pictograms in this group.
3rd meeting planned: August 29, 2018 took place: September 3, 2018 2 hr iSteps 2.1, 2.2, 3	This time, the meeting was planned earlier, after one week, but was postponed because of illness. The meeting was considered the first reiteration meeting (iStep 3). The refinements of the designs that were presented in meeting 2 were discussed, and new designs and content representations were added (iSteps 2.1 and 2.2). Digital prototypes of the pictograms were produced. Other than that, the procedure was the same as in meeting 2. See Figure 32 for examples of digital prototypes for a pictogram of a pleasant fire that radiates *warmth* and for the pictograms *power*, *[warmth] is increasing,* and *[power] is increasing*:

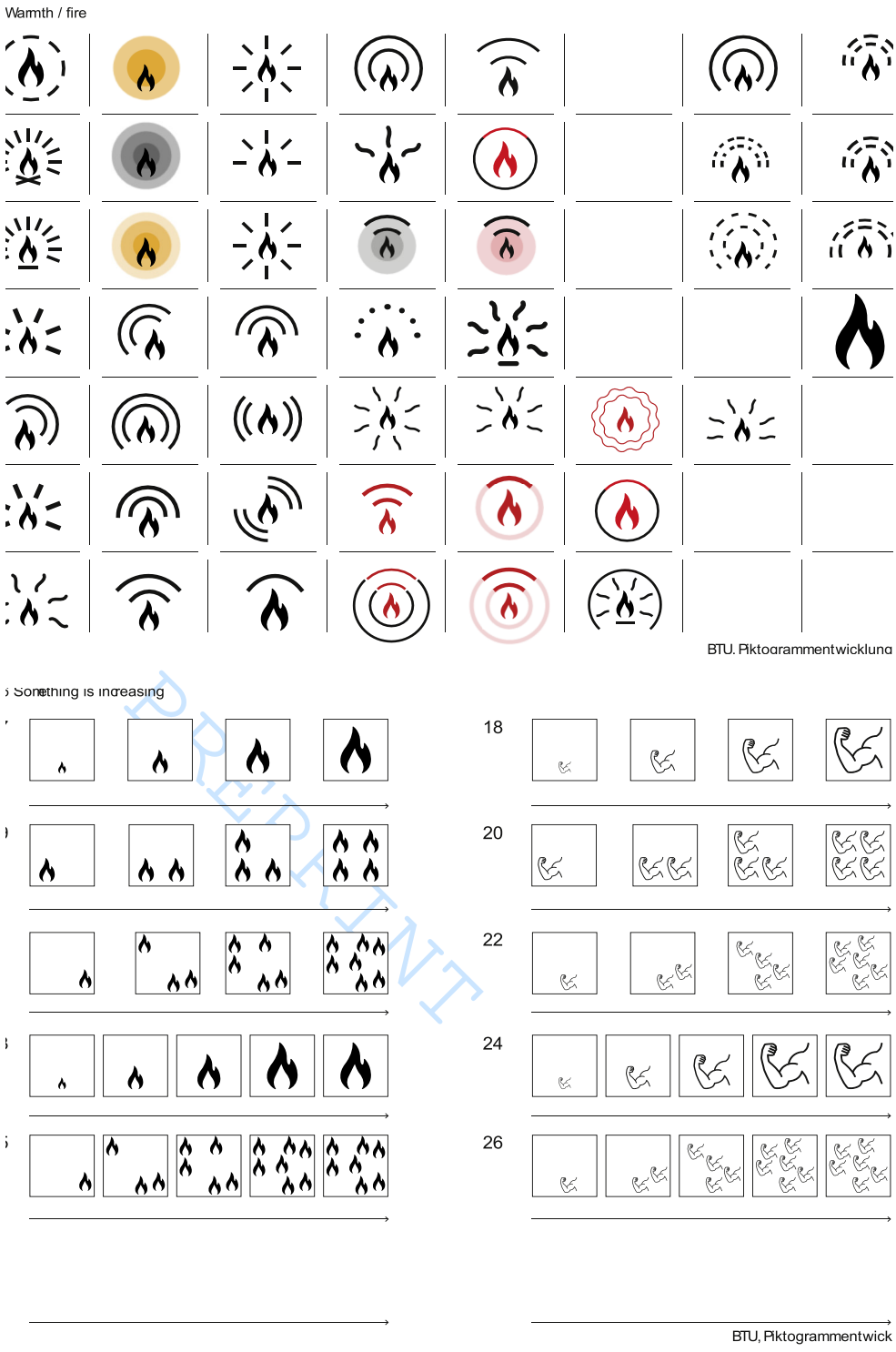

Figure 32. Examples of prototypes for the pictogram *warmth* and the pictograms *[warmth] is increasing* and *[power] is increasing*.

Decisions and findings

It was decided to use *[something or someone] is approaching very fast* as the representational content for the pictogram *[something] is dangerous*, although it was not ranked low (see Section *Discussion, Limitations, and*

Future Research, p. 182) because other contents could not be represented visually in suitable ways (see findings of meeting 2). Furthermore, it was emphasized that contours and movements should be curvy and irregular because real-world shapes of objects are curvy and irregular (see Guideline 2). Shapes should not be straight, symmetrical, or angular (cf. Guideline 10) although this is the established way of designing pictograms. Reproducing conventional designs should be avoided in UIPP (see Figure 33, p. 250). To achieve this, photographs of real-world objects, creatures, and actions from the microstock website Shutterstock (Shutterstock Inc.) [383] were used as the bases of the content designs. In addition, in line with Guideline 36, multiple photographs were used in order to design averaged shapes for typical basic-level contents and to avoid cultural specificity. Figure 34 (p. 251) is an exemplary screenshot of the prototype refinement process aiming for basic-level designs of contents.

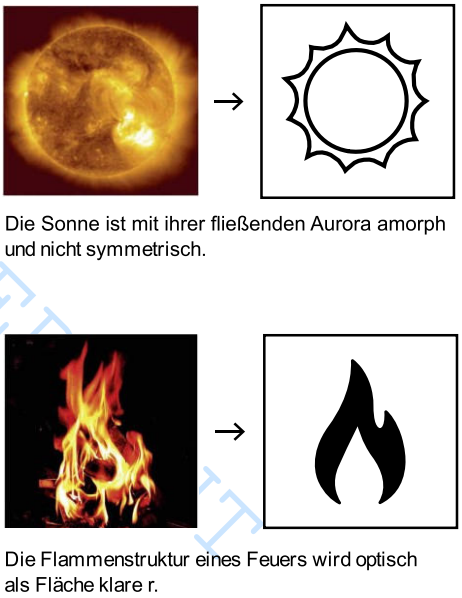

Figure 33. Internal document by the design team regarding the curvy and irregular design of pictogram contents.

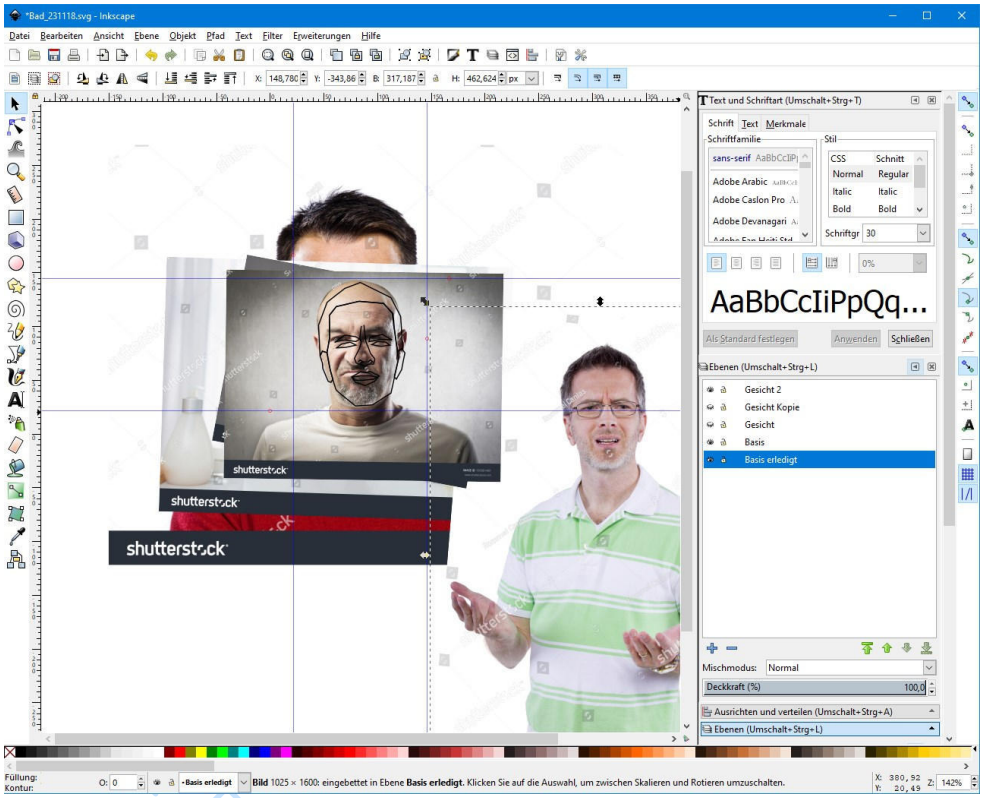

Figure 34. Screenshot during the design of the pictogram *[something] is bad, negative*, using the freeware software Inkscape (The Inkscape Project 2019) [401].

Furthermore, it was decided that colors should not be used in UIPP, although this is Guideline 22. The decision was made after a long discussion within the design team. As mentioned above, it was a technical constraint by the UCUI interface prototype that the pictograms should be black and white, or they should have more than two colors. The latter constraint seemed to go against Guideline 11 because including at least three colors even if an object could be represented in one color seemed to include too many unnecessary details, thus, impede fast recognition. Furthermore, it was argued that the use of real-world colors of objects is not new. Real-world colors have been used for decades, and they are still in use today. Take for example the basic pictograms in Windows, MacOS, and Android operating systems and the Minspeak representation system (Baker 1982) [24]. In contrast, the most innovative guidelines proposed by UIPP seemed to be the guidelines regarding real-world shapes (Guideline 8) and animation (Guideline 27). Since pictogram characteristics are closely interrelated (McDougall et al. 2009, p. 62) [296], the designers assumed that it would increase the difficulty of evaluating the impact of these innovative guidelines if colors were added (see Figure 35, p. 252). This holds, in particular, because the manufacturer pictograms that were reviewed in the first meeting and to which the UIP Pictograms will be

subsequently compared (see Section *Presentation of the Manufacturer Pictograms*, p. 273) are black and white. In other words, the design team was concerned that the impact of adding the common characteristic of real-world colors would render the evaluation of the innovative characteristics of real-world shapes and animation imprecise. Consequently, it was decided that the UIP Pictograms should be black and white, just like the established manufacturer pictograms.

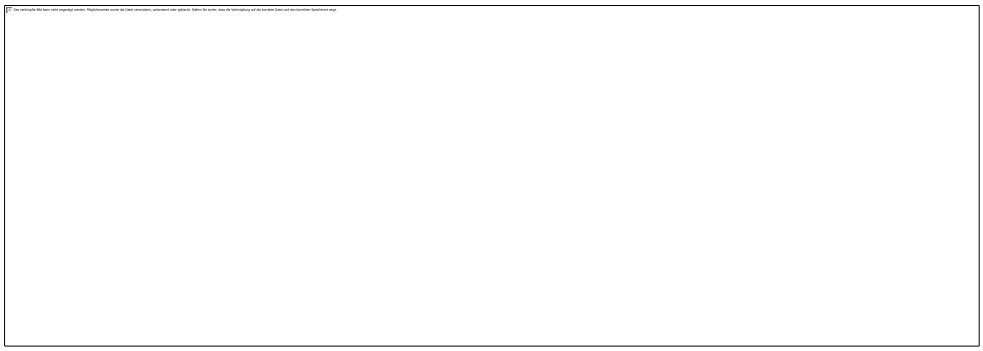

Figure 35. Examples of colored pictograms that were not further refined in favor of real-world shapes and animated pictograms.

4th meeting September 13, 2018 2 hr iStep 3	The structure of the fourth meeting was identical to the structure of meeting 3 (iStep 3). More pictograms were added and more design characteristics, for example, the sizes of the contents, were discussed.
Decisions and findings	With regard to Guideline 12, it was decided that pictogram contents that are big in reality, for example, the sun, should be 10% bigger than normal sized contents, for example, a person. Small contents, for example, a snowflake, should be 10% smaller than normal sized contents. Furthermore, with the intention to design basic-level representations of human beings (Guideline 36), it was decided that faces and people should not be distinguishable with regard to their gender although one derived content for the pictogram *[something] is good, positive* was *the face of a laughing, smiling girl*. However, facial expressions were used because they were assumed to be universal (Plocher et al. 2012, p. 166) [342]. Finally, with the intention to prevent confusion due to reading direction, it was decided that animations should avoid specific directions. Succession should be indicated by representing contents one after another where possible.
5th meeting September 25, 2018 2 hr iStep 3	The structure of this meeting was identical to the structure of meeting 3 (Step 3). See Figure 36 for examples of the pictogram prototypes that were refined and discussed further:

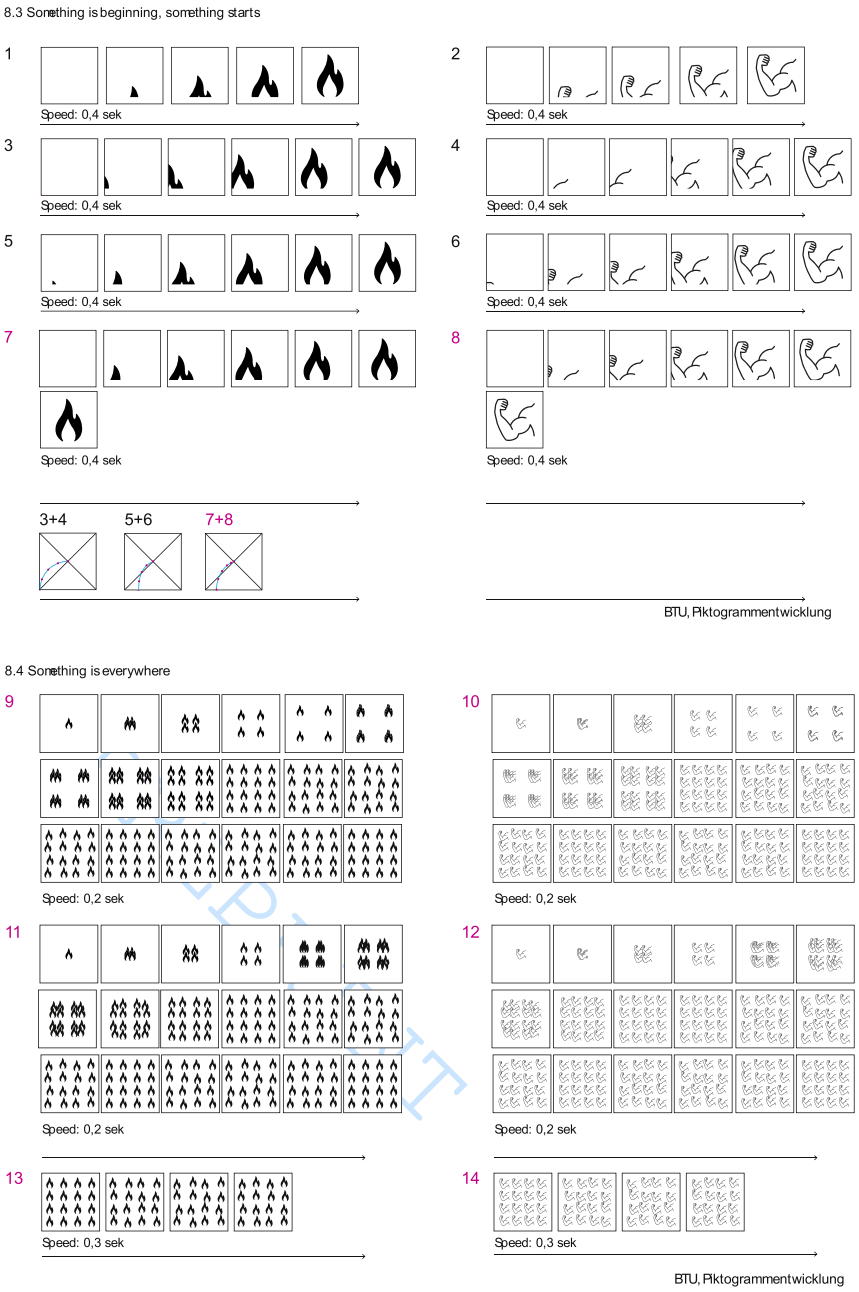

Figure 36. Examples of refined and discussed prototypes in an internal document by the design team.

Decisions and findings

Decisions were made for individual pictograms, for example, regarding the duration and speed of animations. Furthermore, it was decided that animations should always loop. However, there should be two kinds of loops. First, loops that convey to the user that there are a beginning and an ending, thus, indicating that an animation is repeated. Second, loops that appear to run continuously, that is, with no apparent beginning or ending. The first group should be interpreted as representations of actions, for example, *[something] is increasing*. The second as representations of

characteristics, for example, *[something] is good, positive*. For the meaning *[something or someone] is busy*, it was decided that two versions should be designed (see Figure 49 and Figure 50) in order to determine in Study 3 which version is better suited. Finally, for the pictogram of *[something] goes wrong, is wrong* it was determined that it should break into four pieces instead of three because the three-piece version could not be adapted to the design of all additional contents (see Figure 37):

Figure 37. Internal document of the design team that discusses the animation of the compound pictogram *[something] goes wrong, is wrong*.

6th, final meeting October 10, 2018 1 hr	Prior to the final meeting, new prototypes were sent via e-mail (on October 8, 2018) to be able to discuss them during the meeting. The structure of the meeting was identical to the structure of meeting 3 (Step 3), except, only minor changes were discussed that should be made during the finalization of the pictogram prototypes.
Decisions and findings	The designers discussed the finalization of the pictograms. It was argued that the pictograms should be more similar to each other if they were designed for the market. Only then, they would be recognizable as belonging to a set. Since they were not produced for the market, the idea was not implemented.
Finalization Until the start of the evaluation studies: March 23, 2019	The pictogram prototypes were finalized and prepared for evaluation (iStep 4) by the author of this book. In the finalization process, the freeware software Inkscape (The Inkscape Project 2019) [401] was used for the design, and the freeware software GIMP (The GIMP Team 2018) [400] was

iStep 4	used for animation. Freeware software was used with the intention to enable designers, researchers, and businesses with limited resources to follow the process, in contrast to expensive established software. The final contribution by the agency's designers was on October 28, 2018, via e-mail.

Discussion of the Design Production Process

At the end of the design production process, the designers discussed and evaluated the process. It was found that the entire production process was characterized by a continuous back and forth and by leaps between pictogram designs. This is was considered typical for research through design projects (Hemmert 2014, p. 154) [178]. Although the designers considered the process productive, in the beginning, they found it challenging to follow the guidelines mainly because of three reasons: the number of guidelines was considered large, the designers were not very familiar with the guidelines, and the guidelines were often in contrast to established ways of designing pictograms. However, in the course of the process, the designers became familiarized with the guidelines by evaluating before, during, and after the design of prototypes whether these prototypes followed the guidelines. If this was not the case, the prototypes were adapted according to the guidelines that were not followed. Since some guidelines might contradict each other with regard to specific design problems, the designers decided which guidelines to follow based on their skills and tacit knowledge. Furthermore, the design system was considered a result of the process and could not be developed independently from the pictogram prototypes. For that reason, the system was specified at the end of the process. In conclusion, the designers considered the design production process fruitful and instructive for future processes.

Presentation of the Design System and of the Pictogram Prototypes

In this section, the developed design system and the finalized pictogram prototypes are presented. The presentation follows IEC 80416-1:2008 (Deutsches Institut für Normung 2009,