common or rare; whether creativity is domain-general or domain-specific; and whether creativity is quantitative or qualitative" (p. 451).

In our characterization of design as "creative," we use the notion to qualify the activity rather than its result. We use the terms "novelty" and "innovative" to qualify a result that is particularly new and original. Novelty may be the outcome of an activity that is not creative.

Cross (2001a) analyzes the "creative leap" and the "sudden mental insight" (notion for which he quotes Ö. Akin and Akin, 1996), which he considers both as essential in creative thinking. He proposes the notion of "creative event" as the equivalent of the sudden mental insight, for the abrupt, unexpected evocation of a new concept that immediately becomes the design participants' focus. Based on an analysis of the way in which people introduce such a new concept, Cross (2001a) proposes to analyze this creative event, not as a creative "leap," but as a "bridge" between problem space and solution space (see also Cross, 1997). "The crucial factor [in a creative event], the 'creative leap,' is the bridging of [the two partial models of the problem and solution] by the articulation of a concept . . . which enables the models to be mapped onto each other. The 'creative leap' is not so much a leap across the chasm between analysis and synthesis, as the throwing of a bridge across the chasm between problem and solution. The 'bridge' recognizably embodies satisfactory relationships between problem and solution" (Cross, 1997, quoted in Cross, 2001a, pp. 89–90). Cross (2001a) concludes that, rather than regarding creative thinking as mysterious, we now possess "better descriptors of what actually happens in creative design" (p. 97). He mentions problem framing (such as described by Schön, among others), coevolution of problem and solution, and conceptual bridging between problem space and solution space.

A final remark concerns the intentional character of creativity. Creative thinking may appear a deliberate activity that one is happy to engage in. In his study of engineering-design projects, Marples (1961) concluded, however, that the difficulties of the problems to be solved *compelled* designers to "innovate." The elaboration upon the initial solution proposals required hard and ingenious thinking. In the projects analyzed by Marples, "innovation [was] imposed on the [designer] and not sought by him" (p. 67).

17 Representations

"Knowledge" and "representation" are two central concepts in cognition. There have therefore been many debates around "representation" in the cognitive sciences, for example, in relation to "representation versus no representation" (Clancey, 1991; "Dreyfus and Representationalism," 2002; Greco, 1995a, 1995b; Paton & Neilson, 1999; Peterson, 1996; "Representation," 1995; Robinson & Bannon, 1991). Coming from completely different origins, R. A. Brooks (1991) and Dreyfus (2002) have been claiming, each one in a paper titled "Intelligence Without Representation," that intelligent behavior does not require representation.[24] In this book, we clearly claim that intelligent behavior *does* require representation, and that people construct and use representations. Another discussion concerns the "symbolic versus nonsymbolic representation." We come back to this issue, based on Goel's (1995) discussion of "sketches."

Some authors use the term "representation" only in the case of a well-structured formulation (see F. Heylighen, 1988, and other references in that text). That does clearly not correspond to our use of the term.

We wish to stress that, due to its prefix re-, the term "representation" itself is somewhat misleading—the German and Dutch terms "Vorstellung" and "voorstelling" (in English, "presentation") are less deceptive. "Representation," as we view it, should not be interpreted literally: There is no "original," no independent "reality" beyond one's experience to which the representation corresponds. Contrary to representations in AI, the representations constructed by human systems are not more or less faithful replicas of an entity that is re-presented, be it internally or externally.

This position is close to Von Glasersfeld's (1981) "radical constructivism." The two main principles of constructivism are: "(1) knowledge is not passively received but actively built up by the cognizing subject; (2) the function of cognition is adaptive and serves the organization of the experiential world, not the discovery of ontological reality" (Von Glasersfeld, 1989; cf. also Piaget).

17.1. FORMS OF REPRESENTATIONS

Many distinctions are possible here. In the context of designing, particularly relevant are those between internal (mental) and external; initial, intermediate, and final; visual-spatial and verbal-sequential; and private and jointly used representations (cf. what we qualify as "interdesigner compatible representations").

We allot special sections to the discussion of several of these representational forms. There is, for example, a section concerning external representations, because of their centrality in design research, but this special consideration

[24] Vera and Simon (1993a) in their "Reply to Reviewers" in the 1993 special issue of *Cognitive Science* on situated action assert that R. A. Brooks' robots were actually using representations.

should not lead to neglect the importance of internal representations (see, e.g., research on software schemata, Détienne, 2002a). Even if mental representations have received much attention in traditional cognitive-psychology research, we do not possess much data on their possibly specific characteristics in design. It is not because people use external representations that they do not use internal representations. In their "reflective conversations with design situations" (Schön, 1992), for example, designers use internal representations—even if Schön does not highlight this aspect. Using external representations requires internal representations, in a continuous interaction between the two types of representations. As both are being constructed using knowledge, this also emphasizes the central role of knowledge in design.

Representations based on spoken, verbal expressions. Relative to other representations, those based on oral, generally verbal, expressions have at least two specific, noteworthy characteristics.

First, speaking does not allow drafts: Once pronounced, speech is definitive (cf. gestures).

Second, even if one may, of course, record speech, people in normal interactional situations do have no other trace of their interlocutors' statements than their memory (see also J. C. Tang & Leifer, 1988). By contrast, an interesting characteristic of external representations is that they generally leave traces—even if many exploratory drawings are thrown away (McGown et al., 1998). Later on, designers can come back to these residual representations, examine them at ease, and show them to colleagues (cf. research in the domain of design rationale concerning the way and the form in which it may be useful to keep traces of design; see Buckingham Shum & Hammond, 1994; Moran & Carroll, 1996a).

Nevertheless, oral interaction plays an important role in design. Oral verbal interaction, articulated or not with graphical and gestural representations, plays a central role in co-design meetings (Darses et al., 2001; D'Astous et al., 1998; Détienne, Visser, D'Astous, & Robillard, 1999).

17.2. FUNCTIONS OF REPRESENTATIONS

Representations have many different functions and may be used for various aims. Working by means of representations is an interactive process in which the representations one constructs both depend on, and influence the view of one's task. This view evolves, also because of the representations used—whose evolution (through transformation) goes together with one's evolving view. Briefly characterized, representations are tools—cognitive artifacts—

- to keep track of ideas, inferences made, and results and conclusions achieved—be they partial and intermediate, or complete and final.

- to advance understanding and interpretation, and possibly "see" things differently.
- to reach "new" ideas based on "new" interpretations of the representations.
- to derive implications from results already obtained and presented in the representations.
- "to think about situations that [one is] not in or that may not yet exist," "to reason about situations that [one is] unable to experience directly," and to "rely on a kind of 'hypothetical reality' that anchors [one's] reasoning" (Greeno & Hall, 1997).
- to organize one's "continuing work" (Greeno & Hall, 1997; Do, Gross, Neiman, & Zimring, 2000, also mention this organizational function).
- to communicate one's results or conclusions—be they final or intermediate—to other people.

We detail these different functions.

17.3. SYMBOLIC REPRESENTATIONS

Regarding the symbolic nature of representations, we refer to Goel's analysis in *Sketches of Thought* (1995). The author is not "against representation," not even "against symbolic representation." What Goel defends, however, is that the "classical" cognitive-science symbolic representations are not all there is! Especially in ill-structured activities[25] such as design, other types of representation also play an essential role. Based on Goodman's (1969, quoted in Goel, 1995) analysis of symbol systems, Goel explains the essential and typical role played in design by a representational activity qualified as "sketching." Goel's use of this term is not restricted to a particular form of drawing, not even to pictorial symbol systems. In the broad sense that "sketching" has in Goel's work, the term refers to the use of any non-notational symbol system characterized by a certain number of properties. In informal terms, these properties may be qualified as imprecise, fluid, amorphous, indeterminate, and ambiguous (see Table 8.1 in Goel, 1995, p. 182, for the corresponding formal properties, especially their semantically and syntactically dense and ambiguous character).

According to Goel (1995), classical cognitive science is based on what he calls the "Computational Theory of Mind" (CTM), which claims that cognitive processes are computational and require a representational medium (such as Fodor's "Language of Thought") with "some very stringent properties" (p. 3). Among these "CTM properties" are syntactic properties (disjointness, finite differentiation) and semantic properties (unambiguity, disjointness, finite differentiation) (chaps. 7 and 8 *passim*).

[25] Goel follows Simon's terminology.

Goel (1995) does not deny that people's performance in certain tasks (e.g., the classical SIP problems) can be successfully explained by reference to mental representations with CTM properties (chap. 3 *passim*, and pp. 75–76). These properties indeed work for well-structured puzzle problems—they do not, however, for ill-structured, open-ended, real-world problems, such as design, planning, scientific discovery—and neither for the arts. Certain symbol systems used for ill-structured problems do not satisfy several CTM properties, especially syntactic disjointness and unambiguity. Mainly in early phases of the activity, such problems also require other symbol systems. Progressing from early to later design phases, designers use each time less non-CTM systems (such as sketching and particular forms of natural language) and each time more CTM-satisfying representational systems (such as drafting and other forms of natural language). In his conclusion, Goel conjectures that these observations do not hold only for designers' external representational symbol systems, but also for their internal, mental systems.

Recently, Goel has started to establish a link between these results and neurological data concerning anatomical dissociations. He establishes, for example, a relation between the processing of ill- and well-structured information and the different cerebral hemispheres.

17.4. THE OPERATIVE AND GOAL-ORIENTED CHARACTER OF REPRESENTATIONS

Representations are neither "complete" nor "objective." Adapting somewhat Ochanine's (1978) notion of "operative images," we qualify representations as "operative" in that they are, not so much functionally distorted ("distorted" relative to which reference?) and restricted to task-relevant characteristics (Ochanine's view), but *shaped* by these characteristics. Variations in cognitive commitment play an important role in this molding.

Representations are also goal-oriented. They are "constructions, which for some purposes, under certain conditions, used by certain people, in certain situations, may be found useful, not true or false" (Bannon, 1995, p. 67). In more sociopolitically oriented terms, representations are "interpretations in the service of particular interests and purposes" (Suchman, 1995, p. 63). "Even the most seemingly unmediated, veridical representational forms like video recordings do not wear their meanings on their sleeves to be read definitively once and for all" (Suchman, 1995, p. 63). Representational devices are built in order to make things "visible so that they can be seen, talked about, and potentially, manipulated" (Suchman, 1995, p. 63). This visibility is not only for others: An important role in design is played by designers making visible things for themselves, so that, in Schön's terms, they can engage a "conversation" with them, and so advance their design activity.

For Greeno and Hall (1997), representations, "in addition to being representations of something, . . . are for something." The authors examine and practice a view in which they educate pupils to work with representations, especially mathematics, not "just" in order to learn mathematics, but in order to *use* them *for something*, for example, in one of their studies, design. "This contrasts with a common practice in school, wherein students learn to construct representations of information without having a real purpose" (Greeno & Hall, 1997). The reason for which someone wishes to use a representation (e.g., show a decline in a function, or a correlation between two variables) determines, at least in part, the representational form that the person selects. The form depends on the solution process as well. This view also contrasts with a common educational practice, where, in order to solve a problem, students generally are instructed to use standard representational forms and processes depending on the type of the problem.

Greeno and Hall show that people not only use the forms of representation that they have been taught, but also construct novel forms (see research by Hall and other researchers presented in Greeno & Hall, 1997).

Standard notational forms are, of course, also useful, for example, to communicate one's ideas. This quality is due to the existence of widely shared conventions of interpretation. Greeno and Hall (1997) emphasize that teaching the use of such standards to students is thus valuable, but they underline that standard forms have a limitation when their notations are treated as fixed, rather than potential representations that depend on interpretation.

17.5. VIEWPOINTS AND PRIVATE REPRESENTATIONS

In recent years, the notion "viewpoint" has been used in many publications, without having received a clear definition that differentiates it as a particular type of representation. The term is often adopted to refer to the mental representations of design participants that are distinctive due to these participants' specific professional knowledge, domain of expertise, and know-how. However, this acceptance of "viewpoint" does not justify, in our view, the introduction of a specific notion. The representations to which such authors refer do not have characteristics that differ from those generally attributed to "representations." As we have claimed previously, there are no "objective" representations: The influence of people's experience and knowledge, be it professional or otherwise, is one of the factors that influence the nature of their representations. We therefore do not attribute any technical meaning to the term "viewpoint."

We use the term "private representations," when, in the context of collaborative design, we want to distinguish them from the representations jointly used by designers working together—yet, without any theoretical pretension as referring to a particular type of representation. We use the term "personal representation" ill- or well-defined, specification of content area by itself does not imply ill- or well-definedness. The example suggested by Simon to illustrate this is the problem "compose the fugue on the score in my desk." Even if, of the basis of its content area, that is, musical composition, one might have thought that it was ill-defined, this problem has only one correct solution: It does not have any open constraints.

Even if there are indeed no open constraints on the problem's *goal state*, its initial state and the constraints on the *permissible operations* are open—something that Simon and Reitman seem to neglect. We suspect that it is why composers may nevertheless be unable to solve the problem—not because they are unable to find *the* solution!

17.7. PERCEPTS, MENTAL IMAGES, MENTAL MODELS, AND OTHER INTERNAL REPRESENTATIONS

According to Zhang and Norman (1994), different types of representations differentially activate perceptual and cognitive processes. They claim that external representations activate perceptual processes, whereas internal representations usually activate cognitive processes (Zhang & Norman, 1994, p. 118). With Scaife and Rogers (1996); we suppose that things are less systematic, and more complex.

A particular type of internal representations is "percepts," that is, the mental representations that result from perception. They clearly play an important role in design, especially in design of physical artifacts.

In spite of commonalities between imagery (leading to mental images) and perception (leading to—mental—percepts) (see research reviewed in Kavakli & Gero, 2001), there are critical differences between the two processes and their outcomes. Based on a series of experiments, Chambers and Reisberg (1985) conclude:

> One important source of . . . differences between [mental] images and percepts lies in the way each of these comes into being. Perception, initiated by stimulation from an external object, is largely concerned with the interpretation of that object. . . . [Mental] images, in contrast, are constructed as an image of some particular thing or scene. . . . [Mental] images are symbolic. . . . [Mental] images are not *picturelike* [in] that there is no such thing as an ambiguous image. (p. 318)

The experiments presented by the authors show indeed clearly that images are not ambiguous. These results are interpreted by their authors as "arguing against the claim that imagery and perception share a common processing path" (Chambers & Reisberg, p. 326).

Verstijnen and colleagues, in research on mental imagery (Verstijnen, Heylighen, Wagemans, & Neuckermans, 2001; Verstijnen, Van Leeuwen, Goldschmidt, Hamel, & Hennessey, 1998) conclude, "mental images are not inspectable in the same ways as pictures" (Verstijnen et al., 1998, p. 532). One cannot perform the same operations on such internal images as on external images, and these different images will be differentially useful in creativity (see later discussion).

Various cognitive design studies refer to "mental models" and to other, comparable mental representations that are supposed to preserve, in analogue form, features of the represented entity (see Gentner & Stevens, 1983; Johnson-Laird, 1983; Rumelhart, 1989).

17.8. INTERDESIGNER COMPATIBLE REPRESENTATIONS IN COLLABORATIVE DESIGN

Given that they incorporate components from various domains of specialty, design projects generally require multiple skills—and collaboration between them.

The role of representations in collective design varies according to its phases. During distributed design, designers each have their own tasks and specific goals to pursue. When co-designing, they have a common goal that they aim to reach by applying their specific skills and expertise. It is then essential that designers, who each also have their personal, possibly private representations, establish what has been qualified by different authors as a "common ground" (Clark & Brennan, 1991) or a "common frame of reference" (De Terssac & Chabaud, 1990; Hoc & Carlier, 2002). Various other notions have been proposed as related, conveying more or less important differences in view: "Shared context," "mutual referential," "mutual awareness," and "mutual manifestness."

These representations concern agreements, especially on the definition of tasks, states of the design, references of central notions, and weights of criteria and constraints. They are often qualified as "common," or "shared," but given the fact that there is no objective reference, we prefer to characterize them as interdesigner compatible representations (Visser, 2006).

The notion of "compatibility" in this context is based on Von Glasersfeld 's constructivist ideas. In a paper on the legacy left by Piaget, Von Glasersfeld (1997) writes the following:

> In order to live in a society, a sufficient number of our ideas—our concepts and schemes of action—have to be compatible with those of others. And this compatibility confers on them a viability that goes beyond the merely individual. The same goes for the acquisition and use of language. Communication with others requires that the meanings we attribute to words prove compatible with those of other speakers.
>
> Compatibility, however, does not entail the kind of "match" that is implied when people speak of "shared ideas" or "shared knowledge." Compatibility . . . means no

more and no less than to fit within constraints. Consequently, it seems to me that one of the most demanding tasks of AI would be the plausible simulation of an organism's experience of social constraints.

17.9. EXTERNAL REPRESENTATIONS

In recent years, many cognitive design studies have come to focus on external representations.

In domains where the object of design is a physical artifact, for example, mechanical design, "visual representations are omnipresent throughout the design process, from early sketches to CAD-rendered general arrangement drawings" (McGown et al., 1998). Numerous studies examine their use in mechanical design, but also in architecture and industrial design (Do et al., 2000; Goel, 1995; Kavakli et al., 1998; McGown et al., 1998; Neiman, Gross, & Do, 1999; Purcell, 1998a, 1998b; Rodgers, Green, & McGown, 2000; Scrivener, 1997; Tseng, Scrivener, & Ball, 2002; Verstijnen et al., 1998; Verstijnen et al., 2001).

The important role of external representations is, however, not restricted to domains where the object of design is a physical artifact. In today's software engineering, visual languages and visualization as a development and support tool play an ever more important role. The *Journal of Visual Languages & Computing* and the IEEE Symposium on Visual Languages attest to this fact (see the Visual Language Research Bibliography, devised by M. Burnett and M. Baker, retrieved August 10, 2005, from http://web.engr.oregonstate.edu/~burnett/vpl.html). Some authors in this domain who work on user-interface design, cognitive, and other human-oriented issues, are Blackwell, Burnett, and T. R. G. Green.

Forms of External Representations

External representations may take numerous forms: Visual-spatial, graphical or verbal-sequential; two- or three-dimensional; notes, flowcharts, drawings, plans, or scale models (Nakakoji, Yamamoto, Takada, & Reeves, 2000; Newman & Landay, 2000). Among these different forms, drawings—and especially sketches[27]—have received special attention in cognitive-design studies. These representations play indeed an important role in design, particularly in its early phases. Drawing allows to "think through the end of the pencil" (Purcell, 1998a). In a series of studies on mechanical design, Ullman and colleagues have shown the importance of drawing in this domain of design (Staufer & Ullman, 1988; Ullman, 1992; Ullman & Culley, 1994; Ullman et al., 1987; Ullman et al., 1988; Ullman, Wood, & Craig, 1990). According to analyses reported by Hwang and Ullman (1990), "67% of [the marks made on paper] were drawings or sketches.

[27] In the rest of the text, "sketch" is used in its common, restricted sense of a particular type of drawing, and not in Goel's (1995) technical, broad acceptation.

The remaining 33% were text, dimensions and calculations" (p. 343; see also McGown et al., 1998).

"Technical" forms of representation (such as tables, graphs, and equations) are often contrasted with "free" or "artistic" forms of representation (in fields such as painting, sculpture, and literature) and especially with forms that, in addition, allow fluidity and imprecision, such as sketches. Such "creative" forms of representation would be especially flexible; they would be particularly adapted for expressive and communicative use, and open to multiple interpretations (but see Stacey & Eckert, 2003; Van der Lugt, 2000, 2002). Greeno and Hall (1997), however, argue that "representations in mathematics and science also have these properties" and that students might benefit from activities in which they learn to construct and interpret in a flexible way representations that possibly are nonstandard. Such an approach might enable them "to understand and appreciate that mathematical and scientific representations, like those in other domains, are adapted for particular uses" that they perhaps did not expect.

Functions of External Representations

Important functions of external representations depend on the externalization and visualization they allow of preconceptual "ideas" (or "ideas" that will never become concepts), and that may facilitate designing. This holds especially for "graphical," "diagrammatic" (Glasgow, Narayanan, & Chandrasekaran, 1995), or "visual" representations (these different terms are often used for comparable representations). External, graphical representations enable operations on the entity represented that are more difficult or even impossible to perform on internal representations. Using such a representation, for example, it is often easier to "manipulate" an entity, to reason, test hypotheses, and apply other operations on the entity. External, graphical representations often facilitate the discovery or exploration of alternatives, and the prediction of outcomes or consequences of new ideas (Do et al., 2000).

Through the possibilities of simulation, such external representations may be useful in evaluation and in further development of solutions. They serve evaluation in at least two ways. Usually, they are relatively easy to use (compared to internal representations) in order to try out quickly and cheaply different options: The functioning or use of a conceived artifact product may be assessed through its manipulation—even if this operation takes place indirectly, that is, mentally. Juxtaposing various drawings or mock-ups, a designer may compare different possibilities (Do et al., 2000).

These instrumental functions of external representations are essential for designers to advance their design, and work on it through controlled reasoning activities, but also via unintentional and unforeseen discovery. In Schön's terms, the intermediate results of designers' activity, often in the form of external representations, may lead them, in a "reflective conversation with the situation," to evolve in their interpretations, intentions, and ideas for solutions.

External representations—not only graphical—are of course also helpful as memory aids in an extension of internal memory (i.e., in order to temporarily stock provisional ideas, and permanently archive intermediate and final solutions). The storage function of representations concerns not only final representations, nor the straightforward, technical representation of the artifact product, nor the representations communicated to colleagues and other design stakeholders. "As memory for context evaporates over time, supplying sufficient information to enable interpretation is also important for communicating with oneself in the future" (Stacey & Eckert, 2003, p. 163).

Notice that Verstijnen et al. (1998), on the basis of differential results concerning designers' need for sketching, defend that *sketching* is not primarily motivated by memory restrictions (p. 530). Sketching and sketches have other functions. Verstijnen et al. thus contradict the introspective reports of "many artists and designers" who, when asked for their motivation to sketch, "ascribe a function of memory extension to [this] behavior" (p. 530).

Yet, "computational offloading" (i.e., discharging internal working memory) is a function often referred to, even without using this appellation: It refers to the observation that, compared to the use of internal representations, the use of external representations reduces the amount of cognitive effort required to solve informationally equivalent problems (Larkin & Simon, 1987; Zhang, 1997). Indeed, Larkin & Simon have proposed that the perceptual processes that can be applied on external representations allow people to exploit these representations with less effort than the corresponding internal representations, because the grouping together of relevant information in an external representation may make easier processes such as search and recognition.

Graphico-Gestural Representations

In pragmatic linguistics, analysis of graphico-gestural interaction has already a considerable history, but from a cognitive-activity viewpoint, this type of research is just at its beginning (Détienne et al., in press; Détienne & Visser, 2006; Visser, in press; Visser & Détienne, 2005).

In early research analyzing small-group conceptual design sessions, J. C. Tang and Leifer (1988; see also J. C. Tang, 1991) identified the role of gestural activity in "workspace activity." The authors have proposed a framework for the analysis of this activity that establishes relationships between actions that occur in the workspace, and their functions. The "conventional view" of workspace activity considers this space as "primarily a medium for storing information and conveying ideas through listing text and drawing graphics." The authors extend this view, proposing the function of "mediating interaction." In addition to the actions of "drawing" and "listing," they advance "gesture," that is, "purposeful body movements which communicate information, such as referring to existing objects in the workspace or enacting simulations" (p. 245). Besides drawing, which was known to often occur in collaborative-design meetings (46% of the workspace activity, in the authors' analysis), gesture was found to occur frequently: It constituted 35% of the workspace activity, whereas listing made up 19%. The main function of gesture was to mediate interaction between the different design participants: More than half of the gestures (57.5%) served this function through participants engaging their attention.

On the Web site page that presents the research on gesture in her STAR team (Space, Time, and Action Research, retrieved August 16, 2005, from http://www-psych.stanford.edu/~bt/gesture/), B. Tversky notes:

> Although it is typically thought that gestures accompany speech, gestures often accompany listening . . . and non-communicative thinking. . . . In both cases, they seem to serve to augment spatial working memory, much as sketching a diagram would. . . . In collaboration with diagrams, dyads save speech by pointing and tracing on the diagram. Partners look at the diagrams and their hands, not at each other. . . . Having a shared diagram to gesture on facilitates establishing common ground and finding a solution. It also augments solution accuracy.

Sketches

In its commonsense, dictionary acceptation, "drawings" are representations of forms or objects on a surface by means of marks; "sketches" are preliminary drawings for later elaboration.[28] Generally, a sketch is drawn by hand; few computerized systems allow a "real" sketching activity producing "real" sketches (but see Decortis, Leclercq, Boulanger, & Safin, 2004; Gross, 1996; Hwang & Ullman, 1990; Leclercq, 1999).

The characteristics considered useful in initial representations, especially their fluidity and imprecision, are typical of this particular form of drawings. Their meaning may be vague and actually change over time (cf. also Stacey & Eckert, 2003, p. 172, concerning sketches' ambiguity).

Nevertheless, sketching is not the only possibility for designers to offer a wide interpretation space for their representations: Stacey and Eckert (2003) affirm that one can also use precise representations such as photographs of artifact products that are similar to the artifact one is aiming (p. 172).

These relatively unstructured, fluid, and imprecise forms of drawings that sketches are, may give access to knowledge not yet retrieved and may evoke new ways of seeing (because of their non-notational properties, according to Goel, 1995). Unforeseen views on the design project in progress are supposed to open up unanticipated potentialities for new aspects or even completely new directions in the design project.

Based on Stacey and Eckert's (2003) critical analysis of the "myth of beneficial ambiguity," one should be conscious of the crucial differences in potential benefit, both between ambiguous representations in early and in later stages of design, and between their use in individual and in collective design.

Sketches' characteristics related to fluidity and imprecision are supposed to result in enhancement of creativity and innovation in design. However, more than imagery (using mental images) or the use of external representations, what

[28] We are referring here to "idea-sketches." "Presentation-sketches" are not preliminary generally.