Chapter 8

Towards a content theory of context

8.1 Introduction

As should be evident from the previous chapters, context has been attributed to different roles and effects in different areas of research. So, it will be difficult to come up with a satisfying general definition. The notion has mostly been used in language and linguistic, and in psychological studies. Dictionary definitions consider context first and foremost with respect to language. It has been defined as the part of the text which precedes and follows a target word and gives this term its meaning. In a broader definition, context is the whole set of conditions accompanying the occurrence of an event.

In a wide range of areas, context has been declared to influence the cognitive processes. In any process, two kinds of information sources available to a reasoner are the contextual and so called core information sources. In the cognitive psychology experiments surveyed in chapter 7, a word to be learned was the core information, while the color it is printed in was a contextual information.

A thorough context account needs a description of context as well as a specification of the difference between contextual and core sources. It has been a difficult task to place a boundary between contextual and core knowledge. This is probably also the main reason why context does not have a definition that is acceptable in general.

As can be seen from the experimental research in cognitive psychology, context has been used in three different ways. First, especially in early context investigations, context is equated with the environment in which the target is observed. For example the room in which the words are read. Second, context is often concerned with the accompanying features of the target, such as the color of the print. And finally, context is attributed to the mood and state of the reasoner. For example, the reasoner may be drunk or sad. In all these approaches, context is thought to influence the changes in the reasoner’s learning performance.

Our model of context is based on a combination of these three approaches with some extensions and some refinements. In our definition, context is the collection of a special type of information, namely implicitly assumed facts about a problem or a statement, and the goals and intensions of the reasoner. Context is not the conclusion, nor the problem. Yet, it influences the reasoning from the problem specification to the solution.

8.2 Two views on context

At the start of our context investigation, we decomposed this context investigation task, into two more easily achievable main subtasks. Accordingly, we tried to analyse what the notion of context ‘means’ from two distinct but closely related perspectives. According to these perspectives, context is viewed
• as a knowledge type capturing portions of the focus of attention and
• as a means for triggering a shift in the focus of attention

The former perspective leads to analysing and categorizing contextual knowledge, while the latter imposes an analysis and categorization of contextual effects in different areas and tasks.

We utilize the first view in pursuit of studying the context as a knowledge type and investigate how this knowledge can be categorized. This lead to the construction of a context ontology. Then we turn to the second view and elaborate the correspondence between different types of contextual knowledge and the various subtasks of our diagnostic method. The second view takes, as a starting point, a task (in our case diagnosis) and investigates which type of contextual knowledge or information is used in each stage, and in what way various types of contextual information assist these stages. As such, this research subtask deals with the nature of the relationship between a task and the type of the context it relies on.

We may also say that the first perspective adopts a static view, while the second one is more concerned with dynamic aspects of context, i.e., its use.

8.3 Context as a knowledge type

From an epistemological standpoint, context is a type of knowledge. However, a general rule does not exist to determine which knowledge is contextual, and which is not. This is partly because a knowledge “piece” can be of contextual type only with respect to a reference task. Our top-level task is diagnosis which involves an explanation process. Depending on what type of explanation we are seeking and what needs to be explained, we may identify the contextual knowledge. So, we begin viewing context as a type of knowledge by presenting a criterion with which we can hopefully distinguish contextual knowledge core knowledge. The main principle is that contextual knowledge contributes to the explanans explaining the explanandum in an adequate manner. Contextual knowledge is not a part of what is to be explained (the ‘input’ of the task, in knowledge level terms). It is neither the conclusion (the ‘output’ of the task) to be drawn. Notice, for example, that drug abuse is a contextual knowledge w.r.t. a ‘diagnosis’ task, as it may predispose some diseases, but will be a core domain concept when it comes to a ‘prevention’ task. This is because in diagnosis, the overall task of the reasoner is to explain the anomalous observations in terms of a disease concept. In a prevention task, on the other hand, the habit may be the conclusion (output) as it may be what the reasoner is seeking for; the patient should stop drug abuse since it is what causes her disease.

If we consider the entire semantic network in a medical domain, an explanation between a disease and an observation is only a part of a rather extensive explanation which may also include an explanation/connection between, for example, the habit “drug abuse” and the disease “endocarditis”. However, in the scope of a diagnostic task, the reasoner is not always required to come up with the whole explanation of how she found the explanation. Her goal, in the course of diagnosis, is to come up with a disease label and its connection to the findings. This goal does not necessarily include the connection between habits and
diseases, though this would be rather common in a ‘prevention’ task. Hence, the basic aim is an explanation chain between a disease and the observed anomaly, not the explanation of how the reasoner generated the target explanation. However, if the reasoner is required to explain how she came to this conclusion, then she should explain in what way contextual knowledge ‘drug abusement’ governed her reasoning. In other words, “Drug abuse” does not appear in the explanation where the disease endocarditis explains the observed fewer, sweating, etc. Both drug abuse and fever are features of the target object of the reasoning process. However, fever is “core” information while drug abusement is target related “contextual” information. Figure 8.1 shows how “enabling conditions” of a disease are considered, in our approach, as a type of contextual knowledge. These consist of characteristics of the target (e.g., the patient) but are different in their role, from the symptoms and signs observed with the target.

The reasoner uses all possible and easily available types of knowledge in order to achieve her goal. Contextual knowledge helps the reasoner to justify her beliefs and reasoning (i.e., explains to herself), but it may not be relevant when proving that the obtained solution is the true solution of the problem. So, in our account, contextual knowledge plays its most important role in justification of plausible reasoning, such as abduction.

**FIGURE 8.1 The boundary between target-related-context and non-context cues in medical domain.**

### 8.3.1 A model of context - a high-level ontology

This section briefly reviews the criteria used in the literature for distinguishing between various categories of contextual knowledge. We seek a starting point for our categorization of contextual knowledge. There must be some criteria according to which contextual categories can be identified at the highest level.

We summarize the contexts types discussed in the cognitive psychology experiments under three main groups: attributes of the environment, attributes of the target, and attributes of the subject (i.e., reasoner). Our starting point for a context ontology is that problem solving is a deliberate process of which two basic elements are the agent and the external situation. This implies that we do not study problem solving separate from the
problem solver, as has traditionally been done in AI. Recent trends in diverse communities support also our stance [Nardi 96; Baddeley 90; Leger 93]. For example, Nardi criticizes proponents of the “situated action” approach for their insistence on the “situation” as the primary determinant of the action [Nardi 96]. She questions “How do we account for variable responses to the same environment or ‘situation’ without recourse to notions of object and consciousness” (page 89). She considers the difference between three individuals going on a nature walk; a bird watcher who looks for birds, an entomologist who studies insects as he walks, and a meteorologist who gazes at clouds. Even though the “situation” is the same, they behave differently. The difference, according to her, originates from “the subject’s object”.

The behavior of an agent (e.g., a person) is shaped by two important factors: its own personal characteristics or state of mind, and the characteristics of the problem with which it is occupied. Our interpretation of the findings from experiments described in the preceding chapter highlights two important factors which help to maintain context typing. The first is the nature and demands of the process that takes place during learning and remembering. The second factor is the ground facts that happen to exist in a situation. We propose a distinction between internal and external context types in order to reflect these factors, where internal context relates to the former, and the external one reflects the latter factor. The key criteria for this distinction is the deliberate activity of the reasoner. The aspects regarding the reasoning agent are referred to as internal context. The type of cognitive process behind the reasoning is partly decided by the agent itself. The selection of the type of process can also be imposed by giving instructions. This was the case in the experiments related to face recognition. The other alternative is that the subject itself decides how to process the material. This is particularly important in rather complex tasks such as problem solving, where the agent essentially replaces possible instructions with its own choices shaping its own cognitive behavior. In our account, the agent’s decisions are shaped by its goals, hypotheses, and expectations, i.e. the internal context.

External context elements originate outside the reasoner, and consist of two distinct groups of elements: those related to the target and those related to the environment. External context elements basically stay static during problem solving. That is, external context
comprises the static facts in the problem solving situation. For example, in a clinical setting, the agent is the clinician (the reasoner), the target is the patient case, and the environment is the place where the diagnosis and the treatment occur. At the next level of specialization, the internal and external contexts are divided into interactive and independent types - in agreement with Baddeley’s distinction (elaborated in chapter 8). We also differentiate internal-context into interactive and independent, while Baddeley concentrates on external context. That is, he identifies what external context elements are independently or interactively encoded. The top-level ontology is shown in Figure 8.2. Here, the two types of external context, target-related and environment-related, are modeled explicitly.

Notice the difference between our criteria and Hewitt’s regarding the classification of context elements. Our classification takes the agent (i.e. the reasoner) as the main criterion, while Hewitt’s distinction is based on the target as criterion; we are reasoner-centered while Hewitt is target-centered. Hence, in our work, the distinction between internal and external context is relative to the agent, while Hewitt’s distinction is relative to the target. Our target-related context resembles Hewitt’s intrinsic context while our environment-related one resembles his extrinsic context.

Some examples may help to clarify our approach to context typing. First, the independent type: In a medical setting, what the patient is wearing is of type target-related context, whereas the color of the examination room is of type environment-related context. Whether the clinician has short hair is of type independent internal context. Regarding interactive context, for diagnosis and therapy tasks, goals and predictions (hypotheses) of the clinician are of type internal-context, while the pregnancy condition or previous diseases of the patient are target-related. The characteristics (i.e., the conditions and constraints) of the place where the patient-clinician encounter occurs are of type environmental-related context. For example, it is important whether the place is a well-established hospital or an emergency tent in a forest.

8.3.2 Roles of independent and interactive types of external context

Both independent and interactive types of external context constitute cues invoking associations to other entities in the memory (i.e., knowledge base). However their way of associating themselves to other entities are different. In the case of independent context, it is just ‘associated to’ another entity, without clarifying the actual meaning underlying this association. Since the real link between the two entities is often unknown. For example, in medicine, a correspondence between the patient’s gender and a certain disease is known (e., g., statistically), but the underlying reason for this correspondence is not yet known in medical science. This kind of statistical knowledge can be captured within episodic memory by encoding it in the way we called independently. On the other hand, interactive knowledge can be encoded both in episodic and semantic memory, because necessary relations are known. Consequently, independent context can not be utilized in all places where interactive types of context can. Interactive types of context can be utilized both in shallow and deep reasoning, while independent context type can only be used in shallow reasoning. This difference is important for us, because in this work we present a hybrid diagnostic system that commutes between shallow reasoning (case based reasoning) and deep reasoning (explanation based reasoning). During shallow reasoning, both interactive
and independent context can be utilized by the system, while only interactive context is utilized during deep reasoning.

The independent type of context (in fact, independent type of any knowledge) is important, in particular, for weak and open domains.

8.3.3 **Qualitative difference between internal and external context**

It is important to note that the nature of internal and external context elements are qualitatively different. The existing accounts of context consider one of external and internal context, not both. However, a proper account of context should integrate both internal and external elements of context. External context elements are object domain entities. These are rather static and do not change in the course of the whole process. In other words, these are related to ground facts, and either to the target or the environment. The internal context effects originate from the reasoner. Factors such as the goals and interests of the reasoner are vital for the whole flow of the process chain. Also the conclusions that the reasoner draws for a task may constitute a context for the following task. For example, activated hypotheses are a context for the successor task. The notion of goal has drawn much attention in relation to its role in governing and modifying behaviour [Leake 93; Ram 91; Turner 94.] while it has seldom been studied as a context element. However, the human communication community has emphasized the importance of the intention of the speaker as a context type. Also, animal behaviorists recognized what we call “internal context” as a separate type of context pertinent to signal reception, when studying animal communication behaviour [Leger 93].

Internal context may vary across reasoners attempting to solve one and the same problem, however, the external context will be constant for all the reasoners.

8.3.4 **Context role in structuring memory**

It has been reported that experts utilize contextual information to a much larger extent than novices [Devine 95; Custers 96]. The expertise assessments are usually based on speed and accuracy metrics. Expertise can not be explained only by powerful search algorithms, but the amount and type of information must also be of concern for an understanding of expertise.

Association is considered a law of mind [Peirce, 7.388]. Associative reasoning is given prime importance in the context of weak and open domains. Two types of association are commonly recognized in psychology. One is association by “resemblance” and the other association by “contiguity”. Association by contiguity happens when we remember “husband” upon hearing “wife”, that is when a concept suggests another one. Association by resemblance is the type of association when you remember a similar event upon experiencing a new one. Suggestion of one concept by another take place by association, either by contiguity or by resemblance. Both types of association are closely related to the organisation of memory. It has been argued that memory organisation is subjective [Barsalou 92]. People find their own ways to link concepts together. Experts do this better in their own specialities than novices. The fact that experts utilize more contextual information and that experts better organize information may suggest that contextual information plays a substantial role in organizing the memory. Tulvings ‘encoding specificity’ hypothesis is
suggestive both for the subjectivity of memory organisation and for the existence of a relation between context and memory organisation.

The role of context as a knowledge type is that it contributes to clustering, partitioning, and organizing the knowledge of the world which a person may possess. It integrates in a sense, relativity and subjectivity into knowledge. The features of a piano related to “going to concert” (e.g., sound) may be clustered together, while its features related to being a movable object (e.g., size, weight, shape) may also be clustered together and therefore can be accessed quickly when other members of the group are given.

Custers [Custers 96] claims that the medical experience of an expert is organised for each disease as a package with three components, one of which is the enabling context for the disease. He further claims that experts are superior to novices because of their ability to make better associations to these packages.

8.4 Context as a means of focusing attention

Researchers from various communities studying fields such as the generation of explanations, user modeling in communication, natural language processing, and human-computer interaction have all acknowledged the importance of perspective ([Suthers 91]; [Mittal 93]; [Pichert 77]; [Lester 91]). For example, regarding text comprehension, Pichert and Anderson argue that “if, for whatever reason, people take divergent perspectives on a text, the relative significance of text elements will change”. A presumption underlying the notion of perspective is that concepts are represented as a set of features, and not all the features of an item become activated each time the item is activated. Each episode that contributes to the encoding of a concept refers only to a subset of these features. The task context in which a concept is presented determines that particular subset of encoded features. The importance of taking into account the type of task to be accomplished has recently been recognized ([McCoy 89]; [Edmondson 93]; [Cahour 93]).

Our account of the relation between the notions of context and perspective establishes a chain that starts at the goal. It is commonly agreed that goals are of crucial importance for contextualized problem solving and learning (e.g. [Ram 91]; [Leake93]; [Bogdan 94]). The goal invokes a task, which in turn determines the perspective to be taken (see figure 8.3). The perspective pinpoints where the attention needs to be focused. A coherent set of aspects constitutes a focus of attention. For example, the feature weight of the piano is not activated with respect to a going-to-piano-concert event, but it is activated in other task contexts, such as when the piano is to be moved. Hence, the goal determines which aspects of a concept will currently be processed, including both non-contextual and contextual features and cues.

Problems may arise when the perspective is not taken into consideration explicitly. An example may be taxonomies combining multiple hierarchies. Biology is a research area presenting such hierarchies. Suppose that some biologists, being interested in an animal’s habitat, may partition the ‘animal’ class into subclasses ‘sea animal’ and ‘land animal’. Some others, more interested in the dietary habits of the animals, may partition ‘animal’ class into ‘carnivorous animal’ and ‘herbivorous animal’ subclasses. When both hierarchies are integrated in the same taxonomy, ‘whale’ for example should be represented as a
carnivorous animal as well as a sea animal. On a question related to the stomach tooth, whale should be considered a carnivorous animal rather than a sea animal. Thus, the knowledge that is currently relevant is directly related to the perspective that is currently adopted. The knowledge that stomach tooth may be interesting in the perspective of biologists studying the dietary habits would serve a bias toward carnivorous-herbivorous classification.

In our system, the task perspective (see figure 8.3) helps to determine the focal regions both of specific (episodic) and general domain knowledge. The focus of attention is switched when the goal of a reasoner changes. A change in the goal signals that a new task is to be performed. Attention parallels the epistemological needs of the reasoner when engaged in a dedicated task. Therefore, a task is the natural medium for discussing shifts in the focus of attention.

As a result, internal context has a role in determining which features, including both external context and core cues, that are relevant in a particular situation, and how relevant they are. In other words, internal interactive context determines the interactivity of external-context related features as well as non-context ones. Regarding external context elements, this influence is particularly important for tasks in which available information is incomplete, that is, core retrieval cues are not sufficient to access target concepts unambiguously. In such cases, context cues may strongly influence the degree of match between the present material and a past encoded material. Hence, internal interactive context is the main context type that imposes a perspective, which in turn determines the characteristics of both encoding and retrieval.

There has been an ongoing discussion [Brezillon 93] in the ‘context community’ about whether context captures the state of the mind or the situation. In our view, it captures both. A very important issue is to identify and explicate the link between the two components that are pertinent to the context phenomenon. Internal context reflects the state of the mind (of the reasoner) while external context reflects the situation (including both the target and the environment related elements). Internal context imposes the focus of attention, which is captured in terms of core domain concepts, cases, and the other type of contextual knowledge such as external context (see figure 8.4).
This relationship between the “state of the mind” context and “situational” context matches our concerns related to formalizing the link between the “content” and the “process” mentioned in preceding chapters.

### 8.5 Summary

We presented a high level context ontology. The ontology is based on

- *i.* a distinction between internal and external types of context, and
- *ii.* a distinction between the type of encoding

We investigate context from two points of view. According to the first view, we are concerned with context as a knowledge type. In the other view, context is a means for shifting the focus of attention. These two views are not independent.