Deliverable 4.1

Formulation of Initial Model

Contract number: **FP7-215554 LIREC**

LIving with Robots and intEractive Companions

Start date of the project: 1st March 2008 Duration: 54 months

The research leading to these results has received funding from the European Community's Seventh Framework Programme (*FP7/2007-2013*) under *grant agreement* n° 215554.

Identification sheet

Project ref. no.	**FP7-215554**
Project acronym	LIREC
Status & version	[Final]
Contractual date of delivery	1st July 2008
Actual date of delivery	15th July 2008
Deliverable number	4.1
Deliverable title	Formulation of Initial Model
Nature	Report
Dissemination level	**PU** Public
WP contributing to the deliverable	2/4/6/7/8
WP / Task responsible	WP4 T4.1.1
Editor	Wan Ching Ho (UH)
Editor address	Adaptive Systems Research Group, School of Computer Science, University of Hertfordshire, E114C, STRI, College Lane, Hatfield, Hertfordshire, AL10 9AB, United Kingdom
Author(s) (alphabetically)	Ruth Aylett (HW), Kerstin Dautenhahn (UH), Sibylle Enz (Bamberg), Wan Ching Ho (UH), Meiyii Lim (HW), Dag Syrdal (UH), Adam Miklósi (EOTETO), Antal Dóka (EOTETO) and Peter Pongrácz (EOTETO).
EC Project Officer	Pierre-Paul Sondag
Keywords	Modelling memory, long-term autobiographic memory, working memory, emotional memory, remembering and forgetting.
Abstract (for dissemination)	Formulation of initial model linking long-term autobiographic memory and working memory to associated human processes of remembering and forgetting.

CONTENTS

1. Purpose of Document

This document proposes an initial memory model for the long-term companion agent which will be developed and evaluated experimentally in the LIREC project.

This memory model enables the companion agent to remember events that are relevant or significant to itself or to the user. For other events with a lower long-term value, the memory model supports forgetting through the processes of generalisation and memory restructuring. The two main components in our memory model are working and long-term memories. Working memory (WM) supports agents in focusing on the stimuli that are relevant to their current active goals within the environment. Long-term memory (LTM) contains episodic events that are chronologically sequenced and derived from an agent's interaction history both with the environment and the user. Meanwhile LTM also produces concepts as knowledge about the world in order to help in formulating and processing new goals.

There are two key questions that we try to address in this document. The first one is, as a companion agent to a human user, what information should it remember in order to generate appropriate behaviours and thus smooth the interaction with the user? Two important aspects have been taken into account in answering this question: 1) Research into emotional and autobiographic memory within psychology and cognitive science, and 2) ethological studies of "the best human companion animal" - dogs' behaviour and memory. A third consideration regarding this issue is that of social desirability from a privacy point of view. While this issue primarily falls under the description of work for WP 10, it will briefly be considered in this document as well.

The second question concerns the migrating nature of our companion agent - how to design a memory for an agent which can have different types of virtual and physical bodies? To answer this question, we discuss how concepts and knowledge can be grounded in robots' memory and propose a low-level memory design for a migrating agent. Last but not least, the project's existing human-robot interaction scenarios have largely contributed to this design of a memory model. They provide concrete interaction patterns and identify the potential functionality of robotic agents and thus reduce the ambiguity in agent memory content as well as the potential use of this content.

2. Introduction

> *You have to begin to lose your memory, if only in bits and pieces, to realize that memory is what makes our lives. Life without memory is no life at all, just as an intelligence without the possibility of expression is not really an intelligence. Our memory is our coherence, our reason, our feeling, even our action. Without it, we are nothing. - Luis Buñuel. Spanish director, 1900-1983*

Life is full of stories: stories we remember through experiences, stories we heard and stories we compose. These stories are a reflection of "self" when they are told and without them, life is meaningless. An individual without past stories will not be able to appreciate life, share their experiences with others or make sense of anything happening around them. This is due to the fact that "understanding the world means explaining what has happened in it in a way that seems consonant with what you already believe" (Schank and Abelson, 1995). Memories are part of what makes up our personality, controls our behaviours and often influences our mood (Carver, 2005).

Thus, memory is important in any social being. The same argument applies to intelligent virtual agents or robots that are going to establish long-term relationships with human users. The common problem in interaction with computer agents is that users tend to lose interest rapidly due to lack of 'life' and unmet expectations of the character's intelligence and responsiveness. User motivation for interaction decreases with time as agents continue to perform pre-defined rigid sets of repetitive behaviours, leading to user frustration. This problem must be tackled in order to prolong and produce a more engaging and natural interaction between the agent and the user. From the perspective of social intelligent agents, Dautenhahn (1998) argues that the better computational agents can meet our human cognitive and social needs, the more familiar and natural they are, and the more effectively they can be used as tools.

Hence, we argue that inclusion of "human-like" memory in agents will enable them to behave in more natural and believable ways. The existence of memory will help the agents to comprehend their world by adapting to fit new circumstances. It will allow agents to make predictions about a situation and behave in an appropriate way. In other words, an agent's past experiences will serve as guidelines for its future actions. Applying these guidelines, the agent will be able to act in certain ways and hence exhibit a "personality", a reflection of "self" that is important in social communication. The famous Bugs Bunny animator, Chuck Jones, said that it is the oddity, the quirk, that gives personality to a character and it is personality that gives life.

The rest of this deliverable is organised as follows:

- First we will discuss relevant background research into human memory, specifically the nature of remembering and forgetting processes; ethological studies into memory in dogs; and existing computational models of human memory and particularly autobiographic memory.
- Second we will propose a complete memory model for a LIREC companion agent.
- Finally, before the conclusion of the deliverable, we will discuss issues relating to the grounding of experiences for robotic agents and agents that migrate from one platform to another.

3. Background

According to LeDoux (1999), our brain contains a variety of different memory systems that work in parallel to give rise to independent memory functions. Conscious, declarative or explicit memory is mediated by the hippocampus and related cortical areas, whereas implicit emotional memory involves the amygdala and related areas. The hippocampal system lets us remember the details of a situation, whilst the amygdala system produces stimuli that activate our body chemistry for the emotional situation.

Three main activities related to these memories are storage, retrieval and deletion. Information from short-term memory (STM) is stored in LTM through repeated exposure and generalisation. Retrieval involves recall and recognition while deletion is mainly caused by decay and interference.

To investigate further the fascinating research top of modelling human memory, a comprehensive and interdisciplinary literature review for the processes of remembering and forgetting in human, animal and computer programs is provided in Appendix 8.1.

3.1 Computational models of human memory and forgetting

Memory is vital to both humans and dogs as discussed above. The same applies to computational agents if they are to be capable of learning and adapting themselves to their environment. Therefore, modelling a human-like long-term memory has always fascinated AI researchers and led to various memory models contributing significantly to the understanding of human cognition. As discussed in Appendix 8.1, Scripts from Schank and Abelson (1977), captures two important aspects of human memory in the perspective of developmental psychology: 1) it represents everyday events and activities, and 2) it has social and cultural components.

In recent years, the use of temporal sequences of episodic events, in both robotic and virtual agents' research, has been a growing area. For example, by collecting relevant events stored in episodic memory, an explorative robot is able to reduce its state-estimate computation in localising itself and building a cognitive map in a partially observable office environment (Endo, 2007). Also, long-term episodic memory with attributing emotions may help a virtual robot to predict rewards from human users, thus facilitating human-robot interactions in a simple Peekaboo communication task (Ogino, Ooide, Watanabe and Asada, 2007).

Mirza et al. (2006, 2007) uses the concept of interaction histories, defined as the "temporally extended, dynamically constructed and reconstructed, individual sensori-motor history of an agent situated and acting in its environment including the social environment". This work is strongly inspired by dynamical systems approaches to memory and sensori-motor coordination. The approach does not lend itself naturally to virtual characters and believable virtual agents, since the memory content is not represented symbolically and it is thus not straightforward how to visualising it and, more importantly, communicating it to human users, is not straightforward.

The current research trend towards modelling a complete human episodic memory, e.g. episodic memory in Soar (Nuxoll and Laird, 2004) and a generic episodic memory module (Tecuci and Porter, 2007), establishes a common structure that consists of context, contents and outcomes/evaluation for agents to remember past experiences. These models were created to focus on the following three different aspects:

1. Accuracy – how relevant situations can be retrieved from the memory
2. Scalability – how to accommodate a large number of episodes while not decreasing significantly the performance of the system
3. Efficiency – how to optimise the storage and recall of memory contents

Brom et al. (2007) attempted to create a full episodic memory storing more or less everything happening around the agent for the purpose of storytelling. The authors claimed that the modelled episodic memory can answer specific questions from human users in real time regarding the agent's personal histories. With the story scenario which was used in their paper, this memory allowed an agent to describe past actions in time. Forgetting processes were also partially implemented in their work - in the agent's LTM records, less emotionally interesting records were deleted.

Our previous research aimed at modelling the psychological concept of autobiographic memory computationally and integrated it into our synthetic agent architectures. With this memory included, agents are not only capable of recognising and ranking significant events which originate in the agents' own experiences, but can also remember, recall and learn from these experiences. Thus agents' believability can be increased and the interactivity of the software can be more fulfilling for the user (Ho et al, 2007).

Different types of computational memory architectures for Artificial Life autobiographic agents have been developed and experimentally evaluated in our previous research work. For an overview, see (Ho, 2005). These architectures include typical human memory modules which are commonly acknowledged in psychology: short-term, long-term and positively and negatively categorised memories.

Functional decay theory (Altmann, 2000) has been found to be useful in making quantitative predictions for human performance in dynamic task environments. It suggests that encoding and decay are critical to maintaining situational awareness in an environment where tasks change continually. The cognitive system must be prepared to forget so that resources can be concentrated on the current state of the world. The core idea of this theory is that the most recent information must be the most active in memory to allow reliable and fast retrieval. As the current task decays, retrieval becomes more difficult. However, decay through use is minimal, in other words, the more active an item, the more accurately and quickly it can be retrieved from memory. The amount of time invested during encoding determines the amount of decay during use.

Forgetting has been adopted in many learning algorithms. In structural learning with forgetting (Ishikawa, 1996), it is applied to two of the three phases: 1) learning with forgetting, 2) hidden units clarification and 3) learning with selective forgetting. In the first phase, connection weights are constantly decayed so that unnecessary connections can be eliminated and a skeletal network emerges. However, this step may result in a mean square error that is larger than that by back propagation learning. Therefore, in the learning with selective forgetting phase, only the connection weights whose absolute values that are below a certain threshold are decayed. The summation is restricted only to weak connections making the mean square error much smaller than that in learning with forgetting. The determination of the amount of forgetting is important to ensure efficient learning because if it is too large, even necessary connections fade away while if it is too small, unnecessary connections remain, resulting in a network far from skeletal.

Koychev (2000) utilises a gradual forgetting method in learning drifting concepts by applying time-based forgetting function. The idea is comparable to functional decay theory that the most recent information is the most active in memory. Some changes are required to existing induction learning algorithms (eg. NBC, ID3) that treat all training examples as equally important to include a weight for the examples according to its occurring time. By doing so, the last observations become more significant for learning algorithms than the old ones. The result of experiments showed an improved predictive accuracy and adaptability of the systems that adopt learning algorithms with gradual forgetting.

4. Initial Memory Model

In this section we propose our design of initial memory model for migrating companion agents. Taking different aspects from the existing computational memory models (as described in Sub-section 3.1) into account, here we aim to address a companion agent's adaptability to user's preferences as well as the dynamic environment, and the facilitation to long-term interactions with user. Therefore, this model consists of components of LTM, WM and Perception and Action, and Sensory/Actuator Fusions.

The rest of this section introduces the features of each component separately. The low-level design and supports to agent's migrating process from this memory model are discussed in detail in Section 5.

4.1 Overview

By modelling certain features which reflect on the general characteristics of human autobiographic memory and general event representation (GER), our memory model covers different aspects of information processing from low-level to high-level for companion agents. Figure 1 shows an overview of the complete memory model.

To facilitate the long-term interaction between the companion agent and user in scenarios within the LIREC project, the memory model needs to at least capture the user's everyday routine activities as well as the knowledge about the environment for the processes of goal formulation and accomplishment. In addition to that, the enhanced LTM and WM in our model are able to cope with "organic" developmental processes, such as learning new behaviour and attributing emotions to its long-term memories for significant events.

Based on the memory model illustrated in Figure 1, an individual agent can create different behavioural or conceptual meanings for an action or object in its long-term memory, depending on the way it interacts with the user and the environment.

The next few sub-sections are organised in a bottom-up fashion. We will first look at low-level components that allow the agent to perceive stimuli from its environment, utilise the stimuli for goal processing and filter out those that are irrelevant to its current goals (Section 4.2). An agent's experiences and its knowledge represented at a high-level are constructed by contents pre-processed within the low-level components (Section 4.3). The duration of these separate components differs according to the level of granularity involved in their definition.

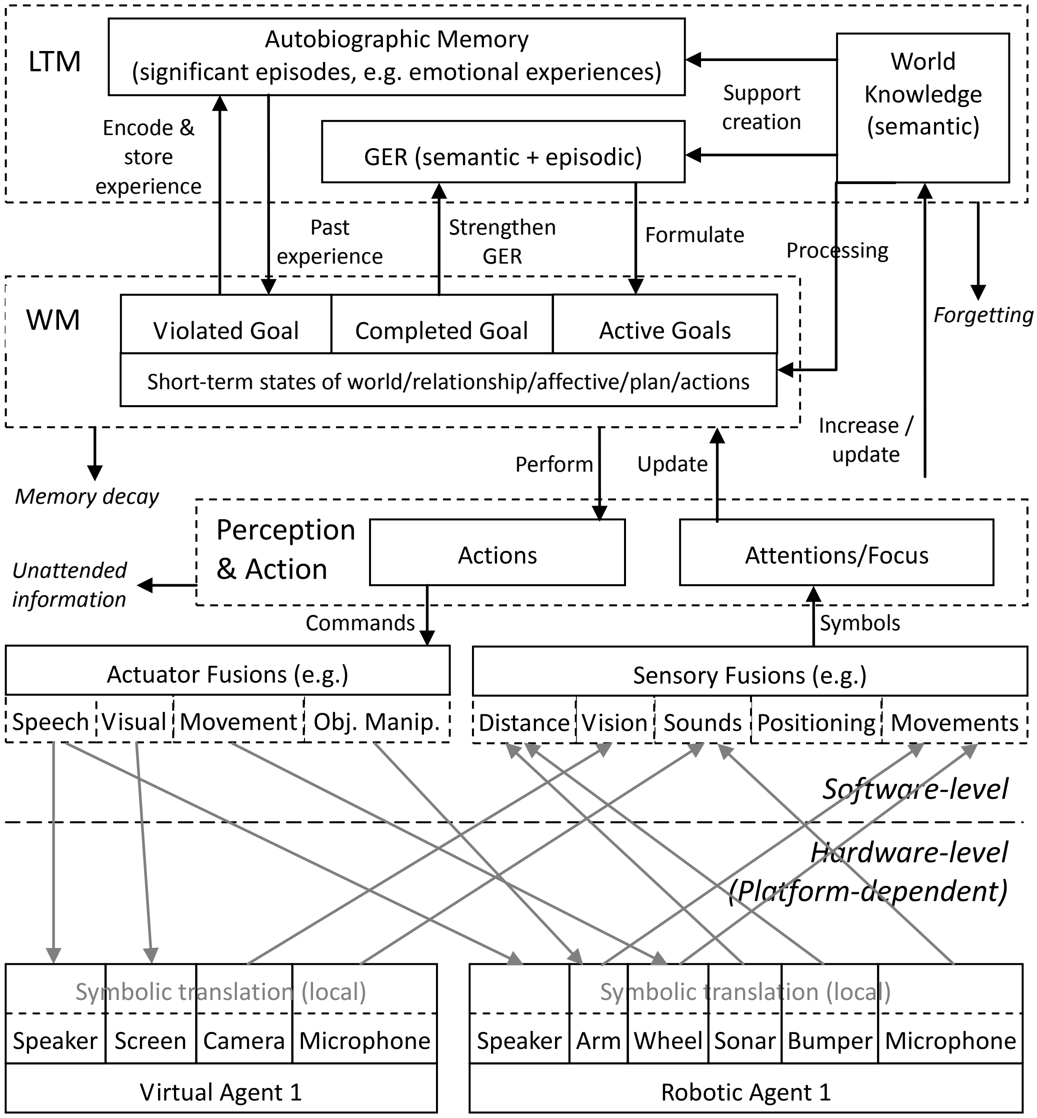

Figure 1: A complete memory model for migrating companion agents, with arrows showing the transition of information among different components. Note that italic labels indicate the effect of forgetting.

4.2 Agents' working memory and perception

As we discussed in the Background section and Appendix 8.1, WM can be modelled computationally to maintain an agent's current focus on its interaction world and activated goals that guide its behaviour performed in the Perception and Action component. In Figure 1 we illustrated the goals management in WM, and how different types of information can be retrieved from other components as well as the influences WM can bring to them. Moreover, WM holds all active information important to the agent’s current and recent goal processing to ensure effective and appropriate reactions to its immediate circumstances.

With the sensory data derived from the fusions of agent's sensors, WM maintains three different types of goals for the agent in order to ensure its adaptation to the environment. These goals are processed, updated and verified with knowledge supplied continuously from LTM. Therefore, the goal structure directs the agent's behaviour in a manner which complements the agent's previous understanding of the environment.

- Active goals: Active goals are formulated in real-time by General Event Representations (GERs) and supported by World Knowledge (WK) modules from LTM (see next sub-section for details of GERs and WK). They are goals that agent need to achieve in a given situation for the reasons of completing a task or satisfying its own motivational states
- Completed goals: Every active goal is continuously monitored in WM and updated with the sensory input. Once the conditions are met and an active goal is achieved, this goal then becomes a completed goal. At the same time this successful occurrence strengthens the same type of goals in GERs – verifying a successful goal will lead to the encoding and further consolidation of the goal in GERs. Therefore, it results in the facts that 1) this goal will be more likely to be chosen for activation in the future, and 2) details of the completed goal will be forgotten by the agent.
- Violated goals: In some cases there will be stimuli that are unexpected or novel to the agent. These stimuli may violate all active goals which the agent tries to achieve currently. The violation of goals leads to the demand for specific past experiences from Autobiographic Memory (AM) in LTM. Since an agent's AMs are constructed from relatively distinctive and emotional experiences in the past (see next sub-section for details), reconstructing these experiences results in updating all active goals in WM, impacting the agent's current emotional states and thus forcing a new regulation of the agent's current behaviour.

These three types of goals maintained by WM are designed to form an iterative loop whose purpose is to reduce the discrepancy between desired and actual goal states. As discussed above, in performing this discrepancy reduction, behaviour is regulated. Newly activated goals emerge from AM can further guide selective attention and actions – this process is necessary to sustain the goal structure.

When a goal is activated, the agent will construct an appropriate plan to achieve that goal. It keeps track of the progress of plan and the state of the environment to ensure that its plan is still valid. Sensory data brought in by the component of Sensory Fusions (SFs) contains the update of the agent’s current environment. Outcomes of current actions – success or failure are noted and alternative actions or plans are established whenever necessary. The agent’s current affective states (emotions, mood and/or drives depending on the agent's emotional model) and its relationship with other agents affect its goal activation.

4.3 Long-term autobiographic memory

To develop companion agents which interact with human users over a long period of time, LTM is the most important component in our model, ensuring that agents learn and adapt socially over the long-term. Supported by the WK module[1], the features provided by AM and GERs are our main foci in developing a comprehensive LTM in the LIREC project[2].

Briefly speaking, GERs are goal categories organised dynamically based on the current goal activity. Their goal-oriented categories can be perceived as memory schemata and scripts since they generally encapsulate all of an agent's knowledge of a particular type of object in the world, or a sequence of perceptions and actions of an event. Knowledge for digesting routine goals - goals that are familiar and do not create emotional impact to the agent - is similar to human semantic knowledge which is used to understand the world. Therefore these event categories provide expectations about what the agent will experience (e.g. see, hear).

When a routine goal from WM is evaluated against existing goals in GERs, if it does not differ from them, it will be "absorbed" into the GERs through rehearsing the categories and its content details can be decay (forgotten) overtime. Therefore routine goals do not have great details in GERs but their schematic structure and meaning are preserved.

As discussed above, WM modulates an agent's behaviour and supports long-term memory construction with knowledge supported from different modules in LTM. Since WM possesses a subset of LTM which are closely connected with the current goal structure and it always monitors the goal accomplishment, external stimuli perceived by an agent will be examined through a "filtering" process in the WM component. A new goal category is created when a novel stimulus cannot be absorbed into existing GERs in LTM - the stimulus is "incomprehensible" by the existing goals and sub-goals in GERs4. Furthermore, as we have discussed, goal verification in WM is a critical and dynamic process in maintaining the coherent behaviours of agents, and it requires retrieving a considerable amount of knowledge from AM based on the current ongoing goal activity. Novel and unexpected stimuli, which can be significant to the agent and may create a considerable amount of

---

[1] Companion agents will need to be pre-installed (or personalised by the user before starting the mutual interaction) a certain amount of semantic world knowledge in the early stage of each scenario (e.g. see Appendix 8.4). This set of semantic world knowledge is necessary to assist basic tasks or interactions that an agent is going to perform, as well as to avoid a user teaching its agent every basic fact of the world at the beginning of the interaction. The knowledge includes, for example, date and time, seasons, user's life routine in different days of a week, objects and resources available in the local environment.

[2] Note that our memory model does not aim to simulate all characteristics of adult long-term and autobiographic memory, but it captures essential features from a number of well developed psychological models. This model establishes the inter-relationship between AM, which provide personal knowledge to support WM based on the given goal activity, and GERs for handling routine and highly anticipated events for agents.

discrepancy between the standard and current state of the world, will affect the agent's emotional states and take part in forming particular sequence of event in AM. For example, in our previous work (Ho et al, 2006), significant events were indicated by a substantial amount of changes in agents' internal physiological variables. Moreover, WK also provides semantic knowledge to support the constructions of important events in AM. These features are illustrated in Figure 1.

Events retained in the AM are different in duration and complexity and they can be seen as highly specific unique experiences. Unlike routine goals in GERs, they also act as organising representations for memories of more specific occurrences. Therefore knowledge constructing these specific events constitutes a central feature in AM.

In summary, both AM and GERs for agent are instrumental in the generation and maintenance of a goal structure. They are also intended to reduce the quantity of information that actually has to be stored and to facilitate a more coherent "self" for the agent to have more consistent behaviour. In order to ensure that each significant event in AM is meaningful and coherent, WK provides semantic knowledge to support the formation of a complete event.

4.4 Forgetting and event generalisation

As reviewed in Section 3.1, forgetting is useful to improve efficiency, scalability and adaptability of cognitive systems operating in dynamic task environments, such as a robot's interaction environments. Therefore, in our proposed memory model, we include forgetting by utilising a decay theory and through memory restructuring. The idea is that memory traces that are of the immediate past are denser than the old ones. When information is perceived, it enters the working memory. With continuous activation through rehearsal or frequent recall this memory may eventually become LTM. However, if the information falls into disuse, the memory trace will start to decay and eventually fade from memory.

The information that receives frequent attention will go through reconstruction processes before it is consolidated as LTM. This is part of the learning process where memory structures are modified continuously based on incoming information to ensure their currency with respect to the world state. By being able to notice and recall differences in experiences, the robot will be able to learn about its environment more effectively. General structures will help the robot in deciding what to pay attention to, and reminding forces it to make use of prior knowledge to form expectations. Care needs to be taken when generalising information to ensure that particular differences that may be valuable are not lost.

The issue of privacy and social desirability may also be addressed through these mechanisms. Previous work on the issue of privacy in relation to robot companions (Syrdal et al., 2007) has suggested that while there are clear concerns regarding privacy, potential users of companions recognise the need for retention and retrieval of information of a personal nature in order for the robot to effectively perform as a companion. Participants pointed towards mechanisms for ‘forgetting’ as vital to address this issue. Thus, mechanisms of forgetting will both address the issue of social desirability as well as those of efficiency, scalability and adaptability.

Taking the robot house showcase (Appendix 8.4) as example, the robot can generalise different types of information in the different interaction scenarios. One generalisation that applies to all scenarios would be finding proxemic distances for different users. Since, the robot will be involved in social interactions, it needs to learn and adapt its interaction style based on users' preferences. In Scenario 1, it has to learn to receive an object, transport and release it without damage. It also has to learn to respond appropriately to the user's requests. In Scenario 2, it must generalise a user's daily routine, for example, the user's habits and tasks. It has to alter its memory about when and how to interrupt and remind the user of those tasks based on the user's feedback. The same applies to Scenario 3 where the robot has to adapt its style of encouragement and type of advice based on the user's likes. Additionally, it can also generalise a route from one place to another, for example, the path for moving from user 1 to user 2. Lastly, in Scenario 5, the robot has to modify its memory structures to the user's interests and ensure that its interaction is consistent across different platforms.

5. Discussions and Implementation Plan

In this section we focus on the components located at the lowest level of the memory model in Figure 1 and related to the physical environment around the agent. Grounding allows symbols to have meaning for agents (usually robotic ones) – symbols must be grounded in the agent's own interaction with the real world. Targeting this issue, we first discuss how to create long-term memory in robots (Sub-section 5.1), and then we propose a method to implement low-level memory particularly for agents which can migrate to different physical bodies.

5.1 Grounding problems – Memory in robots

The problem of grounding has been a huge challenge existing in the research field of embodied Artificial Intelligence for decades. In the LIREC project, our main concern is what defines an experience for an embodied agent. Here we suggest starting by considering an agent's memory as a kind of interaction history, as defined by Mirza (2008, page 9) "the temporally extended, dynamically constructed, individual sensori-motor history of an agent situated and acting in its environment, including the social environment, that shapes current and future action."

In addition to address the grounding problem, this definition has three key aspects (Mirza, 2008):

- Temporal extension: The overall horizon of an agent's experience extends into the past (including previous experience available to the agent) and also into the future in terms of prediction, anticipation and expectation.
- Dynamic construction: This indicates that the history is continually being both constructed and reconstructed. Previous experiences are modified

in both the processes of "storage" and recall, and potentially affect how new experiences will be assimilated into the history in the future.

- Remembering in action: The process of remembering drives and shapes the choice of current and future actions, while also, itself, dynamically re-shaping the structures employed in remembering.

Any embodied agent, particularly a robotic agent, situated and acting in an environment will have many sensors through which it can receive data about itself and its environment. Some sense the external environment (e.g. visual sensors, infra-red distance sensors, sonar sensors), others sense the internal environment and body (e.g. motor position, internal temperature sensors, gyroscopic accelerometers) and others still sense internal variables (e.g. variables that simulate motivational or affective states). Some of these quantities are naturally discrete (e.g. buttons and switches). However, in general the observed quantity is continuous and in current robotic systems the sensor maps the continuous values into discrete observations to some level of precision (Mirza, 2008).

5.2 Low-level memory design for migrating agents

While grounding symbols for robotic agents is a difficult challenge, dealing with agents' migration across different platforms is a further one - the user's social engagement must be maintained when an agent's embodiment changes over time. In particular, when an agent migrates, aspects such as affordances, interaction interfaces and behavioural expressions may be affected.

This sub-section addresses the coherence issue of the agent's memory encoding and retrieving processes associated with different embodiments. As shown in the bottom part of the memory model in Figure 1, the low-level symbolic translation process which is platform-independent can be perceived as the first initial step towards the answer of the partitioned memory. Here we pursue the ideas shown in Figure 1, "Sensory and Actuator Fusions", in which a specific embodiment of the companion agent represents a unique set of interaction histories the agent possesses. Take Sensory Fusions (SFs) as an example; three main steps are involved:

1. Identifying the type of sensors (S1, S2, etc) in each hardware platform (agent’s embodiment), such as:
   - Mobile phone/PDA: camera (S1) and microphone (S2)
   - Kaspar: camera (S3), microphone (S4), servo (S5)
   - PeopleBot: camera (S6), microphone (S7), sonar (S8), bumper (S9), servo (S10)
   - Pioneer: sonar (S11), bumper (S12), laser-scan (S13)
2. Then defining sensory categories (C1, C2, etc):
   - S1 + S3 + S6 -> C1 (vision)
   - S2 + S4 + S7 -> C2 (voice)
   - S8 + S11 -> C3 (Distance)

- S5 + S10 -> C4 (Physical movment)
- S12 -> C5 (Touch sensor)
- S13 -> C6 (Local mapping)

3. Finally a backward mapping is done to physical embodiment of the agent:

- Mobile phone/PDA: C1 + C2
- Kaspar: C1 + C2 + C4
- PeopleBot: C1 + C2 + C3 + C4 + C5
- Pioneer: C3 + C5 + C6

Through creating SFs with these three steps, an agent's memory can be partitioned and incrementally encoded based on the specific platform it has migrated to. During the migration process, the agent comes to the new "body" along with the complete memory, and then it retrieves the right set of SFs to start the encoding process as well as Actuator Fusions (AFs) to execute its planning with behaviours that the current platform can support.

Multimedia content is thus addressed with SFs and AFs. However, as symbolic translations are carried out locally in the specific platform and thus memory component above SFs and AFs can process all types of sensory input and actuator output as symbols, local symbolic translations become a critical process to allow agents to make sense of the surrounding environment as well as to guide its behaviour in changing the environment.

6. Conclusion

In this deliverable we have introduced a comprehensive memory model for companion agents that adapt to its environment and interact with human users for a long period of time. In the model, we use a top-down approach for representing the knowledge and its transfer between components. Meanwhile from a bottom-up perspective we investigate the grounding problem of creating meaningful experiences for robots and how agents can maintain a consistent memory system while migrating from one platform to another. Memory models for virtual agents can be far more sophisticated than those for robots since they easily have access to knowledge about the agent's environment, the agent itself and other agents in the environment (regarding their behaviour, internal states, goals etc.). Such knowledge is not readily available to autonomous robots which rely on their perception and learning abilities. Thus, one of the key challenges for WP4 will be to further investigate such architectures that are suitable for both virtual and robotics agents.

There are certainly many low-level specifications to be done in the near future. Here we illustrate in both LTM and WM components, the conceptual design allowing agents to identify, characterise and distinguish experiences for creating a coherent long-term interaction history.

Finally we expect that LIREC companion agents embedded with this memory model are able to draw on past experience to affect their future behaviour - thus they can go beyond purely reactive or affective and become post-active and autobiographic agents.

7. References

Alba, J. W. and Hasher, L. (1983), Is memory schematic?. *Psychological Bulletin 93*, 203–231.

Altmann, E. M. and Gray, W. D. (2000), Managing attention by preparing to forget. Human Factors and Ergonomics Society Annual Meeting Proceedings, Cognitive Ergonomics, 1(4):152-155.

Bartlett, F. C. (1932), *Remembering: A Study in Experimental and Social Psychology*, Cambridge University Press, Cambridge, Great Britain.

Bouton, M. E., Nelson, J. B., and Rosas, J. M. (1999). Stimulus generalization, context change, and forgetting. *Psychological Bulletin*, 125, 171–186

Brown, J. (1958) Some tests of the decay theory of immediate memory . *Q. J. Exp. Psychol.* 10 12-21.

Brom, C., Peskova, K., Lukavskyz, J. (2007) What does your actor remember? Towards characters with a full episodic memory. In Cavazza, M., Donikian, S., eds.: *International Conference on Virtual Storytelling.* Volume 4871 of Lecture Notes in Computer Science., Springer, 89–101.

Carver, J. M. (2005) Emotional memory management: Positive control over your memory. *Burn Survivors Throughout the World Inc.* http://www.burnsurvivorsttw.org/articles/memory.html.

Cowan, N. (2001) The magic number 4 in short-term memory: A reconsideration of mental storage capacity. *Brain and Behavioral Sciences, 24(1)*: 87-185.

Conway, M. A. (1990) *Autobiographical Memory: An Introduction.* Open Univ. Press, Buckingham.

Conway, M. A. (1996) Autobiographical memories and autobiographical knowledge, in D. C. Rubin (ed.), *Remembering our past: Studies in autobiographical memory*, Cambridge Univ. Press, Cambridge, UK, pp. 67–93.

Conway, M. A. and Pleydell-Pearce, C. W. (2000), The construction of autobiographical memories in the self memory system, *Psychological Review 107*, 261–288.

Conway, M. A., Pleydell-Pearce, C. W. and Whitecross, S. E. (2001) The neuroanatomy of autobiographical memory: A slow cortical potential study (scp) of autobiographical memory retrieval, *Memory and Language 45*, 493–524.

Dautenhahn, K. (1996) Embodiment in animals and artifacts. In *AAAI FS Embodied Cognition and Action*, pages 27–32. AAAI Press, Technical report FS-96-02.

Dautenhahn, K. (1998). The art of designing socially intelligent agents – science, fiction and the human in the loop. *Applied Artificial Intelligence, 12*(7-8):573-617

Endo, Y. (2007) Anticipatory robot control for a partially observable environment using episodic memories. *Technical Report GIT-IC-07-03*, Georgia Tech Mobile Robot Lab.

Eysenck, M. W., and Keane, M. T. (2000), *Cognitive psychology: A student's handbook (4th ed.)*, Philadelphia: Psychology Press/Taylor and Francis.

Halpern, S. (2008), Forgetting is the New Normal, Adapted from Can't Remember What I Forgot: The Good News from the Front Lines of Memory. *TIME: June 9 Issue*, , 36-39.

Harnad, S. (1990) The Symbol Grounding Problem. *Physica D 42*: 335-346.

Ishikawa, M. (1996), Structural Learning with Forgetting, *Neural Networks*, 9(3), 509-521.

Gold, P. E. (1992), A proposed neurobiological basis for regulating memory storage for significant events. *Affect and Accuracy in Recall: Studies of 'Flashbulb' Memories*, 141-16.

Hebb, D. O. (1949) *The organization of Behavior.* Wiley, New York.

Ho, W. C. (2005) *Computational memory architectures for autobiographic and narrative virtual agents*, PhD Thesis, University of Hertfordshire.

Ho, W. C., Dautenhahn, K. and Nehaniv, C. L. (2006) A study of episodic memory-Based learning and narrative structure for autobiographic agents, *Proceedings of AISB 2006 convention, 3:*26-29, Bristol, UK.

Ho, W. C., Dautenhahn, K. and Nehaniv, C. L. (2008) Computational memory architectures for autobiographic agents interacting in a complex virtual environment: a working model, *Connection Science*, 20:1, 21 - 65.

Ho, W. C., Dias, J., Figueiredo, R. and Paiva, A. (2007) Agents that remember can tell stories: integrating autobiographic memory into emotional agents, *Proceedings of Autonomous Agents and Multiagent Systems (AAMAS)*, ACM Press.

LeDoux, J. (1999), The Emotional Brain: The Mysterious Underpinnings of Emotional Life. Phoenix, Orion Books Ltd., London edition

Miller, G. A. (1956) The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review, 63:* 81-97.

Mirza, N. A. (2008) *Grounded Sensorimotor Interaction Histories for Ontogenetic Development in Robots*, PhD thesis, University of Hertfordshire.

Mirza, N. A., Nehaniv, C. L., Dautenhahn, D., te Boekhorst, R. (2006) Interaction histories: From experience to action and back again. *Proceedings of the 5th IEEE International Conference on Development and Learning (ICDL 2006)*, Bloomington, IN.

Mirza, N. A., Nehaniv, C. L., Dautenhahn, D., te Boekhorst, R. (2007) Grounded sensorimotor interaction histories in an information theoretic metric space for robot ontogeny. *Adaptive Behavior 15(2)*, 167–187.

Nelson, K. (1993) The psychological and social origins of autobiographical memory. *Psychological Science, 4*:7–14.

Nuxoll, A., Laird, J. E. (2004) A cognitive model of episodic memory integrated with a general cognitive architecture. *Proceedings of the Sixth International*

Conference on Cognitive Modeling, Mahwah, NJ, Lawrence Earlbaum, 220–225.

Ogino, M., Ooide, T., Watanabe, A. and Asada, M. (2007) Acquiring peekaboo communication: Early communication model based on reward prediction. *Proceedings of IEEE International Conference in Development and Learning (ICDL)*, London, UK.

Peters, C. and O'Sullivan, C. (2002) Synthetic vision and memory for autonomous virtual humans, *Computer Graphics Forum 21(4)*, 743–753.

Richter-Levin, G. and Akirav, I. (2003), Emotional tagging of memory formation - in the search for neural mechanisms. *Brain Research Reviews*, 43:247-256.

Riesberg, D. and Heuer, F. (1992), Remembering the details of emotional events. *Affect and Accuracy in Recall: Studies of 'Flashbulb' Memories*, 162-190.

Schank, R. C. (1982), Dynamic memory: A theory of reminding and learning in computers and people. Cambridge University Press, United States.

Schank, R. C., and Abelson, R. (1977), *Scripts, plans, goals, andunderstanding.* Hillsdale, N.J.: Erlbaum.

Schank, R. C. and Abelson, R. (1995) Knowledge and Memory: The Real Story. In: Robert S. Wyer, Jr (ed) *Knowledge and Memory: The Real Story*. Hillsdale, NJ. Lawrence Erlbaum Associates. 1-85.

Syrdal, D. S., Walters, M. L.,Otero, N. R., Koay, K. L., and Dautenhahn, K. (2007) He knows when you are sleeping - Privacy and the Personal Robot. *Technical Report from the AAAI-07 Workshop: W06 on Human Implications of Human-Robot Interaction*.

Tecuci, D., Porter, B. (2007) A generic memory module for events. *Proceedings to the 20th Florida Artificial Intelligence Research Society Conference (FLAIRS 20)*, Key West, FL.

Tulving, E., and Psotka, J. (1971), Retroactive inhibition in free recall: inaccessibility of information available in the memory stores. *Journal of Experimental Psychology*, 87, 116–124.

Wilkes, D.M., Tugcu, M., Hunter, J. E. and Noelle, D. (2005) Working Memory and Perception. *IEEE international workshop on robots and human interactive communication 2005*, 686-691.

8. Appendices

This session contains extra information as complements that readers can refer to while going through the main body of text in this deliverable.

8.1 Multidisciplinary literature review for remembering and forgetting

Wan Ching Ho (UH) and Meiyii Lim (HW)

An intelligent virtual agent should have the capability to remember and forget information perceived from its interaction environment so that it can update and adapt its memory accordingly. By constantly reconstructing memory, the agent will be able to learn to behave in an appropriate way because its attention can be focused on important information relevant to the current interaction situation.

This reconstructive memory view is supported by Schank (1982) who suggests that our memory is dynamic and we modify memory structures on the basis of mismatches between old and new information, in other words, we use what we know to process what we receive. According to the script theory (Schank and Abelson, 1977), unless under very unusual circumstances, memory traces representing highly typical events in a particular episode will be forgotten while atypical pieces of information are selected to receive special representation in memory. Schank proposed a hierarchical memory structure where a Memory Organisation Packet organizes a set of scenes; a scene (physical, societal, personal) provides general information about an event; while a script provides the specifics of an event. These structures must employ some indexing schemes (eg. goal type, action, object, location, outcome, person, etc.) that allow easy retrieval to enable reminding. He added that plans, goals and themes are memory structures too and there is no fixed set of predetermined structures in memory because we learn to create and modify structures on the basis of our experience.

Bartlett's (1932) work emphasized the reconstructive view of LTM showing that memories are often reconstructed based upon world knowledge and schemata. He is the originator of the schema theory which rejects the notion that memory representations consist of accurate traces that are consistent over long durations. He proposed that 1) human memory has substantial amount of generic knowledge in the form of unconscious mental structures (schemata), such as rules or scripts that can be used to interpret the world, 2) new information is remembered according to how it adapts to these rules and, therefore, 3) errors in recall may occur when the existing schemata interact with the new information.

Alba and Hasher (1983) proposed a prototypical schema theory of memory, assuming the operation of four central encoding processes: "selection - a process that chooses only some of the range of incoming stimuli for representation; abstraction - a process that stores the meaning of a message without reference to the original syntactic and lexical content; interpretation - a process by which relevant prior knowledge is generated to aid comprehension; and integration - a process by which a single, holistic memory representation is formed from the products of the previous three operations" (page 203). In addition, a fifth process, reconstruction, occurs when an individual attempts to reproduce a memory episode. Information stored in memory is reduced through selection, abstraction and interpretation. Incoming information has a selection advantage for retention when a prior schema exists; this schema is activated and the new information is important to the activated schema. However, based on their evaluation of schema theories, they claimed that storing records in human memory is far more detailed than the prototypical schema theory implies because some details are stored independently of a person's prior knowledge and whether that knowledge is activated during encoding. Appendix 8.2 provides some possible explanations for this issue.

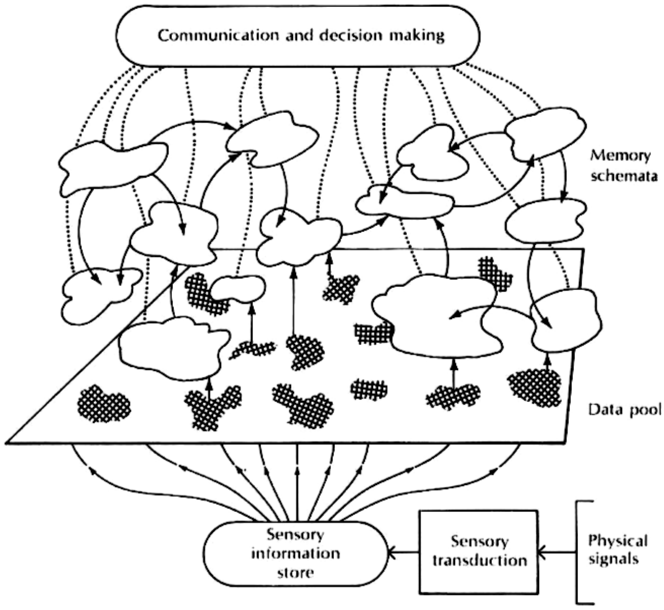

Figure 2: The memory schemata view of the human information-processing system, taken from Norman and Bobrow (1975 page 118).

Drawing on the memory processing theory in cognitive science and schematic memory perspective, Norman and Bobrow (1975) proposed a human information processing system as illustrated in Figure 2. In this system, meaningful interpretations of the world are represented as structural schemas created from past experiences and stored in a long-term storage. These schemas are then used to actively characterize declarative knowledge relating to any experience.

If we were to record every bit of incoming information, we would have information overload, difficulty in organizing the information and difficulty in focusing on one piece of information at a time. Hence, forgetting is essential and useful. Forgetting is also important to prevent stale information from interfering with fresh information. Forgetting can be explained by 1) a decay theory that suggests memory traces fade with time, 2) a reconstruction process that suggests memories are altered, distorted, or modified over time, 3) an interference theory which is supported by empirical findings that suggests memory traces are replaced by new associations, and 4) repression that occurs when memories are unconsciously blocked from our awareness. According to Eysenck and Keane (2000), learning new things through the restructuring of old knowledge and memory helps us to adapt to an ever-changing environment. Interference between memory structures can be either retroactive where information encoded later interferes with information encoded at an earlier stage; or proactive where information encoded at an earlier stage interferes with information encoded at a later stage.

When it comes to recalling information from memory, contextual cues are crucial. Tulving and Psotska (1971) have shown that the absence of a valid cue for recall causes forgetting (cued recall) and if contextual information is missing, memory recall fails. Attention in itself plays a vital role in forming memories and as people get older, their attention starts to flicker which may explain why they forgets more easily due to encoding flaws (Halpern, 2008). Bouton, Nelson and Rosas (1999) suggest that retrieval is most effective when a match exists between encoding and retrieval conditions. They add that a mismatch might occur with the passage of time due to the fluctuation of internal and external contextual cues, hence, reducing the likelihood of the target material being retrieved. Please refer to Appendix 8.2 for a more detail discussion.

Forgetting has also been linked to sleep, distress, exercise and diet. The metabolic processes that take place during sleeping, or more specifically, the heightened stress level that are a direct result of the absence of sleep, influence forgetting. Moreover, the very high cortisol levels that result from dangerous situations and have the function of preparing the organism for flight or attack, damage brain cells if they are not controlled. According to Halpern (2008), exercise can raise cerebral blood volume and boosts a protein that simulates the regrowth of neurons while blueberries may battle highly reactive atoms that damage brain tissue, and hence improve memory.

8.1.1 Working memory (WM)

Providing an interface between perception, LTM and action, WM is a limited capacity system which temporarily maintains and stores information perceived from the surrounding environment. The concept of WM was proposed by Hebb (1949) as a temporary electrical activation, as distinguished from LTM that is based on neuronal growth. Hebb's idea was further supported by Brown (1958) through studies showing that small amounts of information were rapidly forgotten unless actively rehearsed.

There are several important aspects of WM commonly agreed upon by many theorists. First, the amount of information that can be stored in WM was recently estimated by Cowan (2001) as four chunks, which is slightly different from Miller's (1956) suggestion of "seven plus-or-minus two" items in his earlier research. Secondly, WM may be adapted to our perception and thus retain the information that is most important to our current situation. Finally, since information in WM is readily accessible to other cognitive processes, WM contents can be updated and manipulated quickly, and can be easily forgotten - old contents are rapidly discarded while new ones are obtained from the environment.

Recently WM has also been considered an important component to model for enhancing the ability of a software agent or physical robot to learn new skills and tasks through utilising past short-term experiences. There are two complementary approaches that make use of the characteristics of WM:

- Control of attention in memory: focusing on the most relevant features of the current task and allowing for more robust behaviour in the presence of distracting or irrelevant events. This was shown to be an effective way of limiting the search space for perceptual systems. (e.g. Wilkes, Tugcu, Hunter and Noelle, 2005).
- Utilising WM contents in similar ways to those originally developed for LTM: supporting learning that generalises across different tasks. WM can retain a limited amount of information in a temporal sequence for a

rehearsal process to determine whether an item is to be remembered (e.g. Peters and O'Sullivan, 2002 and Ho et al, 2008). This can avoid the "out of sight, out of mind" problem caused by immediate occlusions or confusions.

8.1.2 Emotional and autobiographic memory

It has been widely acknowledged in the memory research literature that events associated with emotional experiences form an important part of highly available memory. Gold (1992) further pointed out that the stronger the emotional factor, the longer the memory remains, and that emotional arousal has a key role in the enhancement of memories with significant information. When experiencing an event with emotion, the human cognitive system is more fully engaged in processing that event, compared to events not associated with emotional experiences.

From a brain science perspective, the amygdala marks an emotional event as important and aids in enhancing synaptic plasticity in other brain regions. This process facilitates the transformation of early-phase memory into long-term memory (Richter-Levin and Akirav, 2003). Furthermore, high level emotionally intense events may also be related to a high frequency of rehearsal - making a piece of memory more generally available for retrieval. Riesberg and Heuer (1992) also proposed a similar idea that emotionally arousing events are more likely to be later recollected than neutral events.

Personally significant events directly involved in the self memory structure, like first time experiences, can create stronger impacts on humans' lives by creating a pre-existing knowledge structure for other similar events (Conway, 1990). These life events, together with events associated with emotions, indicate that central knowledge structures relating to the self have been employed in representing autobiographical memory. In Psychology, autobiographic memory is a specific kind of episodic memory that contains significant and meaningful personal experiences for a human being (Nelson, 1993). It serves important function in providing the basis for social interaction, maintenance of a dynamic self-concept as well as the representation of the meaning of concepts (Dautenhahn, 1996).

Moreover, two features of autobiographic memory are generally defined and accepted by researchers in psychology, as pointed out by Conway et al (2001):

- Autobiographical memories are mental constructions of the self.
- They very often feature imagery while simultaneously containing abstract personal knowledge (Conway 1990, Conway 1996, Conway and Pleydell-Pearce 2000).

Figure 3 extracted from Conway (1996) shows the hierarchical knowledge structures in the autobiographical knowledge base, in which Conway indicated that lifetime periods may themselves be thematically linked together and he showed a work theme and a relationship theme in his past as examples in this figure.

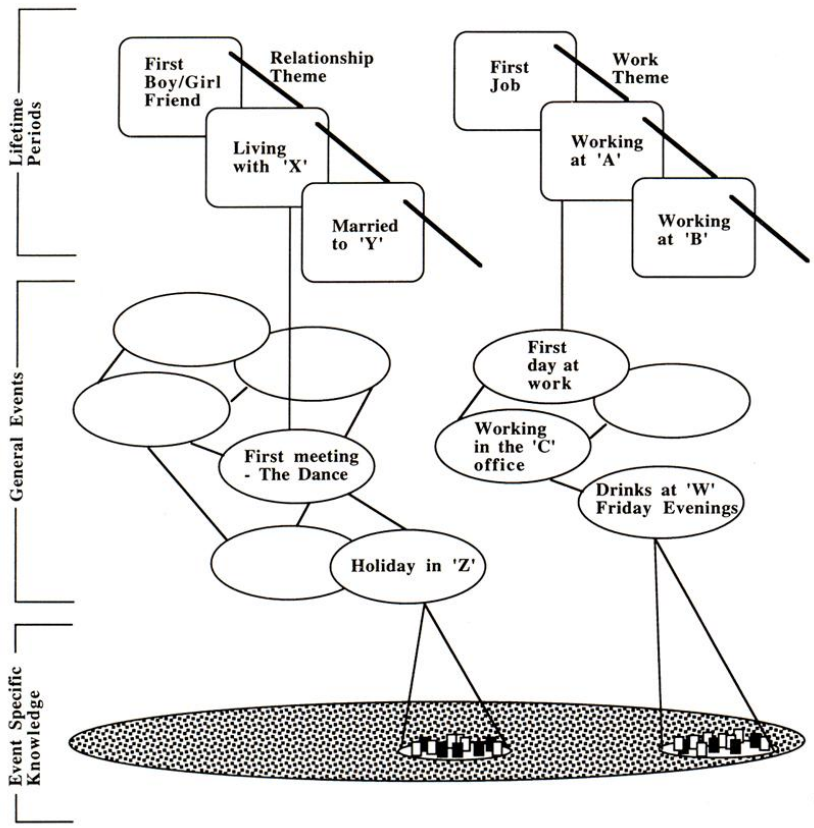

Figure 3: Hierarchical knowledge structures in the autobiographic knowledge base, taken from Conway (1996 page 68).

8.1.3 Ethological investigation – Dogs' memory

Being the earliest companion animal for humans, dogs have been identified by ethologists as possessing good memories. As a human owner interacts with their dog, they can easily notice that the dog remembers many aspects of its life for a long period of time. Therefore, we take into account the investigation into dogs' memory, based on a questionnaire survey of Hungarian dog owners. See Appendix 8.3 for details.

Similar to human long-term memory (as discussed in previous sub-sections), dogs also remember objects, events or living agents, which elicited strong emotions from them. Furthermore, rather than remembering static objects or landscapes, results from the survey indicate that dogs only remember actions associated with their goals at a given time - other non-relevant objects in the environment would be ignored or forgotten in a short time. More importantly, results from the survey also show that dogs have episodic memories - they are able to learn from and recall experience after a single observation or occurrence of an event.

Ethological studies in dog memory, particularly the long-term ones, provide fruitful results for the memory design of companion agents for human user. As the earliest and some would say the best animal companions of humans, dogs' memories help them to learn and adapt to the ever-changing human environment.

8.2 Emotional memory and forgetting in psychology

Sibylle Enz (Bamberg)

EMOTION AND THEIR ROLE DURING THE ENCODING AND RETRIEVAL OF MEMORY CONTENT

Basics

In general, memory works on the basis of three different processes: first, information from the sensory system of the organism (external and internal sensors) are encoded, then stored, and finally retrieved (if not forgotten). It is yet unclear and controversial among scientists, how exactly memory works, but the following chapter introduces some of the ideas that are more widely agreed upon.

Usually, memory is modelled as a succession of three different stores, one for the sensory information, the second for short-term memories, and the last for long-term memories; the above described processes, encoding, maintaining, and retrieving, work on these three entities.

Research questions regarding memory are, e.g. what helps or hinders the retrieval of information from memory, or how does forgetting work?

In the store for sensory information, incoming perceptual input from the sensors is either ignored or paid attention to. In case it is ignored, it is removed quite early. In case one attends to it, it survives, writes over "old" sensory input information, and is processed in order to assess its meaning. Once the meaning is assessed, the information in encoded and transferred to the short-term store. Information that enters this store can be lost either by decay or by interference. The latter can result in the loss of stored information, but also in retrieval errors. Effective strategies to prolong the storage of information in this store are: maintenance or elaboration rehearsal.

Long-term memory keeps a large quantity of information for potentially a very long time. Information stored there can be of very different nature. Factors that influence the retrieval of information from it are for example the similarity of contextual cues during encoding and retrieval, amount of rehearsal, how connected it is to other memories, its significance, etc.

When researching human memory, one faces some serious problems. First, the quality of memory retrieval can only be measured by comparing the consistency of different retrievals at different points of time (indirect measurement). Thus, even if people can elaborate not only on an (emotional) event but also on situational context information surrounding the event, we do not really know whether the retrieved information is accurate (Christianson & Safer, 1996). There are some solutions to this problem, e.g. the simulation of events in the laboratory and the direct assessment of their memories (e.g. subjects are asked to remember pictures with arousing vs. neutral content). However, in the context of memories that have been stored based on real-life events and experiences, the American Psychological Association (APA, 1995) comes to the conclusion that "at this point it is impossible, without other corroborative evidence, to distinguish a true memory from a false one" (http://www.apa.org/topics/memories.html).

The focus of this section lies 1) on the role of emotions when it comes to encode, store, and retrieve information from memory, and 2) on mechanisms behind forgetting.

Impact of Emotions on Retrieving Information

As mentioned above, more significant information is stored longer and retrieved easier than less significant information. But: How can one piece of memory be more significant than another? One way to ascribe significance to memories is their potential to arise emotional reactions. Emotions and memory interact in a rather complex way. Factors that influence the interaction are:

- emotional content (neutral vs. emotional);
- centrality of the aspects that are stored (more important / central vs. peripherical aspects);
- retrieval mode (recall vs. recognition).

In general, emotional and neutral episodes do not differ when it comes to the quality of the retrieval. But there is an interaction effect between emotional content and centrality of the aspects of the episode that are recalled (Christianson & Safer, 1996): Central aspects of emotional episodes are better retrieved than central aspects of neutral episodes, whereas peripherical aspects of neutral episodes are better retrieved than peripherical aspects of emotional episodes. However, the retrieval of peripherical information in emotional episodes can be trained, e.g. through repeated trials to recall them, mnemonics, or after a longer period of time.

These results are in accordance with earlier findings (Easterbrook, 1959) who found that arousal leads to a narrowing of the attentional focus (focus on central aspects). But there need to be other influential factors apart from attentional focus, because the equal distribution of attention (gaze) on central and peripherical aspects of an episode still results in the above described effects (Christianson et al., 1991). (Christianson, 1992) suggest that the encoding of emotional material is qualitatively different from the encoding of neutral material, e.g. central aspects are encoded more elaborately in emotional episodes.

Retrieving Emotional Memories

Christianson & Safer (1996) review empirical findings on the recall of emotions and come to the conclusion that generally accurate recall of emotional experiences is not possible, neither regarding the intensity nor the frequency of emotions. Thomas & Diener (1990) pose that even though the accurate recall of emotional experiences is not possible, one can at least assess interindividual differences regarding the frequency of specific emotions from subjective recalls of these emotions. Levine (1997) investigated the recall of emotions experienced by his supporters when Ross Perrot decided to step back from his presidential candidacy in 1992. He could find quite accurate recalls regarding the intensity of the emotional experiences, but this does not rule out the hypothesis that emotional experiences are reconstructed based on a current emotional appraisal of an event rather than actually recalled (similar findings stem from investigating the memory of pain: rather than recalling the pain, the subjective experience is reconstructed from the recall of contextual information and of own behavioural reactions).

An extreme example for the memory of emotions can be drawn from the therapy of people who suffer from posttraumatic stress disorder (PTSD). These people have experienced extensively stressful events that result in physiological processes which lead to an impairment of coherent memory processes (see excursus below). These people are often “attacked” by emotional memories as a consequence of situational cues that are similar to the traumatic experience but not consciously memorised as part of the traumatic experience; hence, they often cannot recall information about the “where” and “when” of the stressful event. Research into the brain structures and functionalities has identified the Amygdala as the area in the brain that is active when emotional content is stored and processed, whereas the hippocampus is tied to the storage and processing of contextual information. In patients with PTSD, the activation of the Amygdala yields highly stressful emotional experiences that cannot be correctly linked to the contextual information, represented by the activation of the hippocampus. Similarly, some patients suffering from amnesia react with dislike towards persons they have disliked before they got amnesia, but cannot remember knowing them.

***Excursus*: Memory and trauma (Ruf, Schauer, Neuner, Schauer, Catani & Elbert, 2007)**

Autobiographical memory can be broken down in stages according to the level of abstractness: Information can be organised on the level of life stages, e.g. childhood, adolescence, adulthood, etc., on the level of events in general such as going to school, going to work, living in a flat, etc. or on the level of concrete, specific events. The specific memories are organised in networks of sensory information, knowledge about the chronology of the event, appraisals of the event, emotional and physiological reactions attached to the event, and contextual information from the other two stages. Memories of emotions serve – as described above – as a marker for the significance of events and thus to better storage and retrieval. However, the quantity of the physiological arousal that is part of the emotional reaction is crucial: Emotions lead to physiological processes that serve the adaptation of the organism to a challenging situation, but the quantity of the arousal influences whether cognitive processes are fostered or impaired by the stress modulators (e.g. adrenaline, cortisol). Too much arousal impairs the brain’s function and structure, e.g. as a consequence of sustained emotional distress as well as of singular, very stressful events (traumas). This amount of stress leads to reduced neural activity and connectivity and the reduction in volume of certain brain areas like the hippocampus (memory of time and location of events; “cold” memory) as well as to increased activity and elaboration of the amygdala, a brain area that is involved in the emotional memory (emotions, body sensations, sensory input; “hot” memory). Thus, intensive stressful events lead to a dissociation of “hot” and “cold” memory which leads to the activation of “hot” memory structures by situational cues without the activation of the according “cold” memory information, i.e. the “where” and “when” of the stressful event.

Mood Congruent Memory Effects

Mood congruence effects describe the hypotheses that

- positive information is encoded more elaborately if one is in a positive mood and negative information is encoded more elaborately if one is in a negative mood, and
- when in negative mood, negative information is retrieved more easily than positive information and vice versa.

The theoretical models that serve for explaining these effects are

- Bower’s (1991) associative networks, and
- Fiedler’s (1990) dual force model.

Bower conceptualises emotions as nodes in a memory structure that is represented by an associative network. In this network, learning is described as tying information to active nodes in the network (that are, among others, emotions) that are themselves tied to other nodes representing e.g. expressive behaviour, experiences with same emotional valence, etc. Retrieval of information leads to the diffusion of activation in the network which allows for explaining the effects described below.

Fiedler (1990) proclaims two different memory processes: storing information and transforming information. The latter in particular is susceptible to the influence of emotions, i.e. emotional influences are particularly powerful, if learning / memorizing involves the transformation of information.

1. *Mood-congruence and encoding information*

Emotional material is encoded more elaborately than neutral material (as has been described above). Above that, a mood-congruence effect regarding encoding has been proofed experimentally: Positive information is encoded more elaborately if one is in a positive mood and negative information is encoded more elaborately if one is in a negative mood (e.g. Singer & Salovey, 1988). The problem with these experiments is that the experimental induction of mood, e.g. via manipulated feedback of success / failure, does not really ensure qualitatively different mood states, but also arousal which acts as a confounding variable with its own influences on the quality of encoding (Revelle & Loftus, 1992).

2. *Mood-congruence and retrieving information*

In neutral mood, positive information is retrieved more easily than negative information (Matt et al., 1992). A mood-congruence effect regarding retrieval for negative mood / depression (Matt et al., 1992) can also be shown: When in negative mood, negative information is retrieved more easily than positive information. However, such effects regarding the retrieval in positive mood can only be shown if the information at stake is related to one-self.

These effects were found in the laboratory, using induced mood states, but could be replicated in the field with natural occurring mood states (Mayer et al., 1995).

3. *Mood-congruence between encoding and retrieving processes*

Findings from research into drug abuse show that under the influence of a drug, people remember things from their last drug experience; hence, drug experience serves as a key stimulus for encoding and retrieving information (Baddeley, 1997). The transfer of these findings to the influence of mood on encoding and retrieving however yields mixed findings (Bower & Mayer, 1985). Kenealy (1997) traces these mixed findings back to methodological problems and reports findings that mood can act as a key stimulus for retrieving information, but only if other – more powerful – stimuli from the situational context are not present (cued recall).

Memory Deficits due to Emotional Influences

Depression and negative mood is associated with impaired cognitive performance, in particular if the tasks at hand require high cognitive effort / the use of cognitive resources (Hartlage et al., 1993). These effects are also true for memory processes: In particular, effortful processes like the elaborate encoding of information, their organization within the memory structures, or the use of mnemonics are impaired when in negative, depressive mood (as compared to neutral mood; Clore et al., 1994). The problem with experiments in this area is: The estimation of the amount of cognitive effort is very subjective and hard to assess. Different assumptions are applied in empirical studies but not verified, e.g. recalling something after a longer period of time is regarded as more effortful than after a shorter period of time.

Findings are backed up by investigations of the so-called "implicit memory", i.e. memory content that influences a person's behaviour but need to be remembered consciously and thus eat up less cognitive resources. Indirect measures applied to assess implicit memory content do not yield effects for negative mood, but, as Roediger and McDermott (1992) point out, indirect measures can not be directly compared to direct memory assessment measures, since they emphasise perception abilities rather than conceptual aspects of the material (explicit memory tasks do the opposite).

Theoretical explanations for the influence of negative mood on memory performance:

- Depression consumes cognitive resources (Ellis & Ashbrook, 1988; Hertel, 1998) through symptoms like pondering, ruminating, etc.
- Motivational deficit: Depressive people are less motivated to engage in effortful memory processes (Hertel, 1994); their performance can be improved under explicit guidance, e.g. to use mnemonics.

Anxiety yields rather mixed results regarding its influence on memory processes. Eysenck & Calvo (1992) speculate that anxious people also suffer from the leakage of cognitive resources due to the emotional experience (a.), but that they are extremely motivated to allocate cognitive effort (rather than the motivational deficit of depressive people; b.) and thus are able to make up for these impairments. But this compensation strategy can only work for processes that demand low to medium cognitive effort; it collapses when highly challenging memory processes are required.

Forgetting

There are basically two theories that try to explain how forgetting works: the first, the decay theory, suggests that memory traces fade with time, the second, the interference theory suggests that memory traces are replaced by new associations. Empirical findings back up the second approach and show that forgetting does not work just as a function of time (memory traces begin to fade and disappear, if they are not retrieved and rehearsed), but rather as information being replaced by new information. The competition between old and new information seems to be functional: Learning new things helps us re-structuring old knowledge and memory structures, helps us to adapt to an ever-changing environment (Eysenck & Keane, 2000). Interference between memory structures can be either retroactive or proactive: retroactive interference means that information that is encoded later interferes with information that is encoded at an earlier stage; while proactive interference means that information that is encoded at an earlier stage interferes with information that is encoded at a later stage (witnesses in court etc.).

When it comes to recalling information from memory, contextual cues are crucial: Tulving & Psotska (1971) have shown that forgetting is due to the absence of a valid cue for recall (cued recall) and that recalling memories fails if contextual information is missing. As Bouton, Nelson & Rosas (1999) put it: “Retrieval is best when there is a match between the conditions present during encoding and the conditions present during retrieval. The passage of time can create a mismatch because internal and external contextual cues that were present during learning may change or fluctuate over time. Thus, the passage of may change the background context and make it less likely that target material will be retrieved“.

Influences on forgetting have been researched with regard to sleep and distress. The research into the influence of sleeping on memory and forgetting can be subsumed with the finding that not the sleeping as such, but it is rather the metabolic processes that take place during sleeping that influence forgetting. Results focusing on the absence of sleep on memory and forgetting can be interpreted as being at least partly the consequence of heightened stress levels that are a direct result of the absence of sleep.

As far as stress level and memory is concerned, the excursus above already explains the effects of adrenaline and cortisol on brain functions: extensively high cortisol levels that result from dangerous situations and have the function to prepare the organism for flight or attack, damage brain cells if they are not controlled; normally, internal regulative mechanisms stop the distribution of cortisol within a short time frame, but this control mechanism can be impaired, e.g. in depressive patients.

Motivated forgetting: Sometimes, the retrieval of memories is possible but is actively and consciously suppressed (due to negative emotions attached to it), especially those of traumatic or disturbing events or experiences. As opposed to suppression, repression is the purposeful, but subconscious block of memories. These strategies to “forget” disturbing experiences have been researched in psychoanalysis as defense mechanisms, strategies that serve to protect the self from situations and emotions with which one cannot cope (Freud, 1937). In case of these unconscious or conscious strategies of motivated forgetting, remembering, discussing or rehearsing memories, e.g. during a psychotherapy, are important techniques to strengthen the retrieval of the suppressed or repressed memories. Similarly, forgetting details of disturbing events might also be due to the fact that disturbing events are simply less often discussed and rehearsed than positive memories.

References:

Baddeley, A. D. (1997). Human memory: The theory and practice (revised edition). Hove: Psychology Press.

Christianson, S.-A. (1992). Emotional stress and eyewitness memory: a critical review. Psychological Bulletin, 112, 284-309.

Clore, G. L., Schwarz, N., & Conway, M. (1994). Cognitive causes and consequences of emotions. In R. S. Wyer & T. K. Srull (eds.), Handbook of social cognition (2nd ed., pp. 323-417). Hillsdale: Lawrence Erlbaum.

Bouton, M. E., Nelson, J. B., & Rosas, J. M. (1999). Stimulus generalization, context change, and forgetting. Psychological Bulletin, 125, 171–186.

Bower, G. H. & Mayer, J. D. (1985a). Failure to replicate mood-dependent retrieval. Bulletin of the Psychonomic Society, 23, 39-42.

Christiansen, S.-A., & Safer, M. A. (1996). Emotional events and emotions in autobiographical memories. In D. C. Rubin (ed.), Remembering our past (pp. 218-243). New York: Cambridge University Press.

Christianson, S.-A., & Loftus, E. F. (1991). Remembering emotional events: the fate of detailed information. Cognition and Emotion, 5, 81-108.

Easterbrook, J. A. (1959). The effect of emotion on cue utilization and the organization of behavior. Psychological Review, 66, 183-201.

Ellis, H. C., & Ashbrook, P. W. (1988). Resource allocation model of the effects of depressed mood states on memory. In K. Fiedler & J. Forgas (Eds.), Affect, cognition, and social behaviour (pp. 25-43). Toronto: Hogrefe.

Eysenck, M. W., & Calvo, M. G. (1992). Anxiety and performance: The processing efficiency theory. Cognition and Emotion, 6, 409–434.

Eysenck, M. W., & Keane, M. T. (2000). Cognitive psychology: A student's handbook (4th ed.). Philadelphia: Psychology Press/Taylor and Francis.

Freud, A. (1937). The Ego and the Mechanisms of Defence. London: Hogarth Press and Institute of Psycho-Analysis.

Hartlage, S., Alloy, L. B., Vazquez, C., & Dykman, B. (1993). Automatic and effortful processing in depression. Psychological Bulletin, 113, 247-278.

Hawkins, S. A., & Hastie, R. (1990). Hindsight: Biased judgments of past events after the outcomes are known. Psychological Review, 107, 311-327.

Hertel, P. T. (1994). Depressive deficits in memory: Implications of research and theory for memory improvement following traumatic brain injury. NeuroRehabilitation, 4, 143-150.

Hertel, P. T. (1998). Relation between rumination and impaired memory in dysphoric moods. Journal of Abnormal Psychology, 107, 166-172.

Kenealy, P. M. (1997). Mood-state-dependent retrieval: The effects of induced mood on memory reconsidered. Quarterly Journal of Experimental Psychology, 50A, 290–317.

Levine, L. (1997). Reconstructing memory for emotions. Journal of Experimental Psychology, 126, 165-177.

Matt, G. E., Vazquez, C., &, Campbell, W. K. (1992). Mood congruent recall of affectively toned stimuli:A meta-analytic review. Clinical Psychology Review, 12, 227–255.

Mayer, J. D., McCormick, L. J., & Strong, S. E. (1995). Mood-Congruent Memory and Natural Mood: New Evidence, Personality and Social Psychology Bulletin, Vol. 21, No. 7, 736-746.

Revelle, W., & Loftus, D. A. (1992). The implications of arousal effects for the study of affect and memory. In S. Christianson (Ed.), *The handbook of emotion and memory* (pp. 113–150). Hillsdale: Lawrence Erlbaum.

Roediger, H. L., & McDermott, K. B. (1992). Depression and implicit memory: A commentary. Journal of Abnormal Psychology, 101, 587- 591.

Ruf, M., Schauer, M., Neuner, F., Schauer, E., Catani, C., & Elbert, T. (2007), KIDNET - Narrative Expositionstherapie für Kinder. In: M. Landolt, T. Hensel (Hrsg.) Traumatherapie bei Kindern und Jugendlichen. Göttingen: Hogrefe.

Singer, J. A., & Salovey, P. (1988). Mood and memory: Evaluating the network theory of affect. Clinical Psychological Review, 8, 211-251.

Thomas, D., & Diener, E. (1990). Memory accuracy in the recall of emotions. Journal of Personality and Social Psychology, 59, 291-297.

Tulving, E., & Psotka, J. (1971). Retroactive inhibition in free recall: inaccessibility of information available in the memory stores. Journal of Experimental Psychology, 87, 116–124.

8.3 “What does my dog remember?” – An ethological investigation into the memory of human companions

Adam Miklósi (EOTETO), Antal Dóka (EOTETO) and Peter Pongrácz (EOTETO).

We asked Hungarian dog owners about the memory of their dogs. We did not give them too many instructions, we just told them to categorize the particular dog memories by their longevity. We used four categories (see the last columns of the table).

We sorted the answers into broad categories by the content of the memory.

Each colour marks an individual dog along the table. One owner was an exception, Professor Vilmos Csányi. He did not fill in our questionnaire, but his cases were collected in a book he wrote on his dog experiences. His dog cases are marked in yellow.

It is interesting to see according to dog owners, dogs have quite good memories. The big proportion of long-term memory cases may indicate that dogs truly remember particular things for a long period of time.

In our experience dogs mostly remember things, events or living agents, which elicited strong emotions from them. The usual targets of dogs’ memories are: other animals, their owner, the postman, very pleasant or unpleasant events, fearsome events, objects with strong positive or negative meanings. .

The memory of a dog is built around actions. None of the owners reported cases with static objects, landscapes etc. Dogs most probably have an excellent capability of ignoring the majority of their environment. They only remember the most relevant things that happened to them. Objects or persons which were only there but did not do anything interesting or relevant skip the dogs’ memory.

Based on these questionnaires, we can see that dogs are able to learn and recall something after one event. On the other hand, most of the cases might involve several repetitions, so we do not know actually how many events were needed for the dog to build up a memory of these.

Scenario				**no memory**	**short term mem.**	**long term mem.**	**very long term mem.**
With whom/what	**Action (what happens – what does the dog do)**	**Where**	**When**				
prey	a cat or rabbit turns up – the dog chases it	on an excursion	any time			x	
'prey'	In general my dog is VERY interested in other animals, with the exception of dogs. A few examples: wild boars, squirrels, mice, deer. She likes to track their trails and chase them. She kills and eats little rodents. The memory we are talking about is connected to the PREY itself.	excursions	Irrelevant NOTE: as these meetings are very rare and occasional, I cannot tell if my dog remembers for a very long time to the given situation and place, because the chance for repetition is scarce.			x	
Cat	The cat is one of the most relevant things for my dog. Mentioning the word "cat" elicits an immediate search response, and if we are on a locality where my dog met once with a cat, she will check it out at first on the same exact place. My dog chases the cat, but does not catch or kill it.	Anywhere, but especially on localities where we have already met with a cat.	Any time (maybe with the exception of totally counter-motivating situations, like going to the Vet, or being in				x

			the show ring).				
Sheep, livestock	My dog is a herding breed, and she did some herding here and there. Even if she smells sheep from the car as we are passing by a flock, she becomes excited.	Anywhere, I guess	Any time				x
'Matthew', the male roedeer	Matthew was a tame roedeer, with whom the dog grew up together. Once Matthew caused serious injury to the dog, since then the dog is afraid of alive roedeers in the forest. If the roedeer was already shot down, the dog is not afraid.	At home/in the forest	In 2 years of age				x
Wild duck	The dog did not retrieve the shot down ducks for a long period. Then once he found one accidentally, and he was praised a lot about it. Since then he retrieves enthusiasticly, even he could catch wild ducks alive a few times, too.	On a hunt	6 years of age			x	
Duck	Since a duck attacked the dog, he is afraid of them.	At home	4 years of age				x
Barking at the hedgehog	The dog barks at the hedgehogs every night, in vain he is yelled at to stop.	At home	Every summer	x			
The cat at home	They are buddies, but if they had a quarrel, the dog growls at the cat for a while	At home	Any time		x		
Hedgehog	If the dog finds a hedgehog, he starts barking at it and tries to catch it – he becomes more and more furious after being stung a few times. If we tell him to stop this, he stops.	On a walk, in the courtyard	Any time	X			
The cat of the	The dog likes to lick the cat. The guests put the	At home	1993			x	

guests	cat in the bathroom, and the dog shows the next day that he still would like to go to the bathroom for the cat.						
'Dodo', the pigeon	Dodo was a shot down and rescued pigeon. The dog looked at the pigeon's place on the top of the cabinet, long after the pigeon was gone.	At home				x	

OTHER DOGS

Scenario				no memory	short term mem.	long term mem.	very long term mem.
With whom/what	**Action (what happens – what does the dog do)**	**Where**	**When**				
Familiar dog	These are the other dogs at home. My dog greets them and if they are not at home, seemingly “misses” them a little bit. When they meet again, I know that she recognized them because the meeting lacks the extensive investigating behaviour, but immediately goes to a quick greeting.	Usually at home	Any time			x	
Other dog	My dog is not fond of strange dogs, if they are not from the same breed as she. Anyway, my dog seems to forget quickly other dogs, and when we meet with them again, carefully examines them.	Away from home	Any time		x		

THE OWNER

Scenario				**no memory**	**short term mem.**	**long term mem.**	**very long term mem.**
With whom/what	**Action (what happens – what does the dog do)**	**Where**	**When**				
owner	comes home by car – the dog runs to the gate when the car is still very far	in the garden (anywhere?)	every time			x	
owner	daily routine activity – dogs extrapolates	in the flat, in the garden	as usual			x	
owner	takes leash – ready for walk /to go	at home /anywhere	any time				x
Owner (me)	I am the center of my dog's life. She does almost everything in relationship to what I am doing. She knows exactly the routine of my daily activity. She has expectations for example when I have to return from work. As this time approaches, she becomes alert and reacts with great excitement to phone calls for example (usually I call my wife when I come home).	Anywhere	Any time				x

FAMILY MEMBERS

Scenario				**no memory**	**short term mem.**	**long term mem.**	**very long term mem.**
With whom/what	**Action (what happens – what does the dog do)**	**Where**	**When**				
father other members of family	(verbal) punishment - ?	anywhere	any time		x	x	
Mum	When my Mum arrives home with the car, the dog recognizes the sound of the engine from a big distance.	At home in the garden (maybe anywhere?)	Any time				x

STRANGERS

Scenario				no memory	short term mem.	long term mem.	very long term mem.
With whom/what	**Action (what happens – what does the dog do)**	**Where**	**When**				
neighbour	coming home by car – nothing	in the garden	any time	x			
stranger	strange person turns up during the walk – frightened (remembers place)	familiar route	any time (darkness?)			x	
guests guests giving treat /have dog	come to visit – nothing special show interest next time	at home	any time	x		x	
Strangers	My dog remembers more or less to those strangers who did something relevant for her (positive or negative). If these experiences are repeated, her memories will last longer. For example, one of my students performed repeatedly experiments on my dog, when she had to bark into a microphone. Years after she still distinguishes this guy, and she is ready to bark at him. The neighbor lady used to tease my dog from behind the fence. My dog does not forget it, and I have to be very careful, because she	Not important	Not important	X?		x	

	would attack this woman on the street. In general, my dog does not show particular signs of remembering other people, whom we just meet sometimes, but nothing relevant happens.						
Kids biking, skateboarding, playing with a ball	The kids playing on the street always teased the dog through the fence, threw stones at him, so the dog is very furious towards them.	Mainly in the courtyard, sometimes on the street.	Any time			X	
Kids biking, skateboarding, playing with a ball	The kids playing on the street always teased the dog through the fence, threw stones at him, so the dog is very furious towards them.	Mainly in the courtyard, sometimes on the street.	Any time			X	
Neighbour	When the dog and his owner went for a walk, the neighbour stopped them and told to the owner that when they will come back from the walk, he wants to give them something, So when later they returned from the walk, the dog stopped at the neighbour, as he would remembered that they had to do there something.	At home				x	

THE VETERINARIAN

Scenario				no memory	short term mem.	long term mem.	very long term mem.
With whom/what	**Action (what happens – what does the dog do)**	**Where**	**When**				

vet	vaccination – frightened	clinic	first time				x
vet	The dog likes to travel with car, but when he notices that they have arrived at the vet, he does not want to get out.	At the vet	When they go to the vet				X
vet	The dog behaves normally in the waiting room, sniffs the other dogs, plays with the people. But when the time is there to go into the vet's office, the dog only crawls on the floor	At the vet	When they go to the vet		X		

THE POSTMANScenario				no memory	short term mem.	long term mem.	very long term mem.
With whom/what	**Action (what happens – what does the dog do)**	**Where**	**When**				
Postman	When the dog hears the sound of the postman's bike, he starts to rage at the gate, and tries to bite the postman's hand as he puts	Only at the gate, if they meet with the postman on the	When the postman				X

	the newspaper into the mailbox	street, the dog ignores him.	comes				
Postman	When the dog hears the sound of the postman's bike, he starts to rage at the gate, and tries to bite the postman's hand as he puts the newspaper into the mailbox	Only at the gate, if they meet with the postman on the street, the dog ignores him.	When the postman comes				X

CAR

Scenario				no memory	short term mem.	long term mem.	very long term mem.
With whom/what	**Action (what happens – what does the dog do)**	**Where**	**When**				
Car of the owner	Recognizes the sound of the car	At home	Any time				X
Car	The dog traveled by car only once, and since then he wants to get in always, in vain it is forbidden for him	At home	In puppyhood				x
car	The dog traveled by car only once, and since then he wants to get in always, in vain it is forbidden for him	At home	Any time	x			
Car	If he hears the sound of our car, he runs to greet us.	anywhere, if the car is ours	Any time			X	
Car	If he hears the sound of our car, he runs to greet us.	anywhere, if the car is ours	Any time			X	

ACTIVITY IN GENERAL

Scenario				no memory	short term mem.	long term mem.	very long term mem.
With whom/what	**Action (what happens – what does the dog do)**	**Where**	**When**				
play	on a walk a stick is left behind – looks for it next time	familiar area	any time		x		
Activity	My dog remembers the special activities, which she likes to do together with us: for example going for a walk, going to play, travel with car. In these cases the slightest sign, which tells to her that any of these events will happen soon, elicits great excitement from her, and she starts to show intentional activities. At the same time I did not observe the same good memory capacity with unpleasant activities.	The usual place mostly	Any time				x

UNPLEASANT EVENTS

Scenario				**no memory**	**short term mem.**	**long term mem.**	**very long term mem.**
With whom/what	**Action (what happens – what does the dog do)**	**Where**	**When**				
pain	unsuccessful jump – avoiding obstacle	dog school	any time			x	
hot	touching hot coffee with nose – frightened (remembers word „be careful" after 1 experience)	at home	first time				
traumatic event	wasp bite – frightened (remembers sound of wasp, but often does not discriminate well)	anywhere remembers place	any time				x
Long, thin stick, or metal arrow in the hand	Punishment is coming, or can easily follow, if she does not stop whatever she does (usually when she barks furiously at the fence towards somebody) – the dog becomes humble, comes slowly with her head held low, wags tail low	Mostly at home, somewhere else I have to give the verbal command, too	Any time				x
Bucket	Once accidentally a bucket of hot water was poured onto him, since then he is afraid of the bucket	At home	2 years of age				X

Laundry on the drying line	He steals it, in vain he gets punishment for it	At home	Any time	x			
Football	Once the ball hit him badly – he is afraid of it	During walk	puppyhood				x
Smell of the sausage	Once he got food poisoning from eating bread with sausage sauce. Since then he does not eat sausage	At home	A few weeks ago			x	
Cutting of hair	My Mum cuts the hair of the dog. After such an event the dog hides in the house and avoids my Mum for a while, when he hears her voice.	At home	Once per a year		x		
Rug	When he is being hit by the rug during playing tug-of-war, he whines a little, but continues the game.	At home	Any time	x			
Floor washer broom	Once he chewed apart this tool, he was beaten with the remaining part, since then he is afraid of it	At home	Any time				x
Thunderstorm, fire crackers, firework	He is afraid of it, he comes to us, looking for a safe, calm place	Mostly at home. During a walk he is not so afraid of it	Any time		X		
Thunderstorm, fire crackers, firework	He is afraid of it, he comes to us, looking for a safe, calm place	Mostly at home. During a walk he is not so afraid of it	Any time		X		
Luggage	If the owner brings the luggage, the dog becomes sad, because he knows that somebody will travel away.	At home	Any time				x

PLEASANT OBJECTS, PLACES, EVENTS

Scenario				no memory	short term mem.	long term mem.	very long term mem.
With whom/what	**Action (what happens – what does the dog do)**	**Where**	**When**				
Collar, ball, short stick	Walk, excursion, play is coming – she becomes exuberantly happy, barks, jumps, spins	Anywhere, but the reaction is stronger, if the situation is familiar	Any time				x
Cornfield	Always goes out to the cornfield, in vain he gets punishment for it	At home	Any time	x			
Feeding bowl	The dog guards it all day, if there is food in it.	Anywhere	anytime		X		
Opening of the gate	When we open the gate for the car, the dog tries to go out to the street. We punish him for doing this, but he still tries to escape, so we usually close him in somewhere.	On the courtyard	Any time				X
Sound of the chaincollar	When he hears this sound, starts to jump and fuss around	anywhere	anytime			X	
Treat, clicker	When the dog sees these, the reaction is the same like before the walk: the dog knows, what will happen and he is very happy	Outdoor or indoor	Any time		X		
Ball	The dog rarely plays alone, usually reacts to the ball only when I call him to play.	Outdoor only	Usually when I come home		X		

			from work afternoon				
Walking stick	The dog is very happy, when he sees the stick, because this is the signal of an excursion	At home/ on holiday	Any time				x
Leash	It means walking, the dog even points at the leash with his nose, if he wants to go.	At home	Any time				x
Riding a sledge	Once the kids in the park took the dog for a ride on their sledge. Next day the dog ran ahead, and checked out if the kids were there again.	On a walk				x	
Biscuit	He was given a biscuit from a particular bag. A few days later he was still touching sometimes the empty bag, showing his interest in more biscuits.	At home				x	
Key of the cellar	The dog was only once in the cellar with his owner. A year later, when the owner took again the key of the cellar, the dog started to go down the steps.	At home	1990				x
Order of clothes	The dog will prepare for a walk only if the owner pulls on his shoes at first, and then goes for the leash.	At home	Any time				x
Sound of the camera	The dog will move, when he hears the click of the camera.	At home			x		

8.4 Scenarios in UH robot house

Robot House Showcase @ UH: Preliminary Outline Scenarios

(UH team) Dag S. Syrdal, Kerstin Dautenhahn, Michael L. Walters, Wan Ching Ho, Kheng Lee Koay

General notes regarding the use of scenarios in LIREC:

This document proposes five preliminary Outline Scenarios relevant to the Robot House showcase in LIREC. Outline Scenarios are abstract scenarios that are not specific to a particular robot or hardware design (the general structure has been inspired by Outline Scenarios for robot assisted play for children with special needs as part of the FP6 project IROMEC, cf. Robins et al. 2008, IEEE RO-MAN).

The scenarios are kept "pragmatic" in the sense of being able to implement them with the existing technology today and the new technology we will develop in LIREC. They will serve to showcase the novel developments within LIREC. Note, as part of experimental investigations within the WPs we may also use more "futuristic" version of these scenarios, i.e. scenarios that project into the future in order to inform developments *beyond* LIREC. But this is different from the scenarios in this document which are meant to "work" at the end of LIREC (in terms of working robotic/agent prototypes with no or very little "wizard-of-oz" or other shortcuts).

I. Fetch and Carry

Key idea:

A mobile robot assisting in the transportation of objects

Human-robot relationship:

Robot as an assistant, assisting with tasks requiring physical activities

Actors/Roles:

One user is involved in this scenario. Particular needs addressed in this scenario could be minor physical impairment making walking while carrying objects difficult. This may also include people who e.g. due to an accident or other conditions cannot walk well temporarily (e.g. using crutches). For the wider population fetch and carry tasks could be termed an added "convenience" of a robot that assists in the home (for instance carrying plates and cutlery when a member of the household is serving dinner).

Activity Description:

This particular activity allows the robot to assist the user in carrying objects around the home. It consists of the user manipulating a physical object and placing it in/on a particular part of the robot which is suitable for transporting it to another location.

Motivations for the user:

Allows for greater ease in moving objects around the house

Increases independence and allows for a greater range of activities

While assistive, still requires movement and actions on the part of the user, thus increasing the amount of physical activity available to the user rather than decreasing it.

Activity Model:

The user places an object on the robot/hand an object to the robot, then either instructs the robot to follow, or instructs the robot as to the desired location. The robot and the user move to the specified location at which point the user removes the object from the robot and moves it to its final position.

Place/Setting:

This activity takes place in the house as a whole, possibly and likely encompassing more than one room. Required for the activity is that the rooms are laid out in such a fashion that initially manipulating the object as well as placing it on the robot does not require movement of the actor. Likewise, the final position of the object should be reachable by the actor without the actor having to move.

Artifacts/Media:

Robot Capable of Movement in space and Transport:

- The robot needs to be capable of following the user/move to the user
- The robot needs to be able to sense and respond to the user appropriately.
- The robot needs to be able to receive, transport and release the object

Time/Flow:

This particular activity is driven by the user's needs and capabilities, the movement speed of the user regulates the time needed for completion.

Research Questions include:

- Co-transport/collaboration
- Efficacy – How useful do participants find the robot’s behaviour
- Acceptance/user experience – How do users experience the assistance

II. Agent as Cognitive Prosthetic:

Key idea:

An agent (robot or otherwise) serves as a memory aid reminding user's of certain tasks, possibly involving migration from robot to virtual embodiment or vice versa. The task is completed when the relevant object(s) to carry out the task have been found by the agent/user.

Human-robot relationship:

Robot as a cognitive prosthetic, providing help with mental tasks

Actors/Roles:

One user is involved in this scenario.

Activity description:

The agent reminds the user of tasks that need to be completed as well as offer advice on objects that are necessary to complete the task.

Motivations for the user:

This activity helps the user in organising her day and thus reducing the need for intervention by third parties to assist the user.

This activity also enables the user to perform tasks more easily and efficiently, thus freeing up time.

Activity Model:

The agent determines that a certain task needs to be completed by the user: This can be due its knowledge about the user's regular schedule, or may have been predefined by the user or a third party.

If the agent can communicate with the user in its current embodiment, it will inform the user of the task. It will also inform the user which objects are required to complete the task.

If the current embodiment is stationary and unable to communicate with the user, it will change autonomously to a mobile embodiment to find the user, before providing this information.

If the user is aware of the location of the objects then the agent will confirm that the task is completed before ending the activity.

If the user needs help locating the objects, the agent will volunteer its knowledge of the objects' locations if the agent is aware of this.

If the agent is not aware of the locations of the objects, it will move to a mobile embodiment and help the user search for the objects.

Once the objects are found, then the agent will confirm that the task is completed and end the activity.

If the user refuses to perform this task, the agent will end the activity or inform a third party.

Place/Setting:

This activity takes place in the house as a whole, possibly and likely encompassing more than one room. Required for the activity is that the rooms are laid out in such that allows one or more of the different platforms for the agent to search for the objects needed to carry out the tasks.

Artifacts/Media:

This task can be completed across several platforms. The system as a whole need to be able to:

Locate and communicate with user

Search and recognise relevant objects.

Time/Flow:

This particular activity is driven by the needs of the user as defined by the required tasks. These tasks may have been set by the user or a third party.

Research Questions include:

- Acceptability of robot behaviour
    - Issues of setting the task – User vs. Third Party
- Robot Interaction Style – Terse vs Agreeable?

III. Telepresence Card Game:

Key idea:

This activity is allows two players to interact in a game-like fashion, using an artificial agent as mediator between the user and other people.

Human-robot relationship:

Robot as a mediator/tool for entertainment

Actors/Roles:

The game is played by two players, who take turns leading the game.

Activity description:

The game is quite similar to the Mastermind board game, in which one player lays six cards in front of the agent, allowing the agent to memorise the sequence. The other player then has to lay the cards out in the correct sequence using cues from the agent as their guide.

Motivation for players:

This game allows for the players to engage in social interaction

This game also allows the players to exercise their cognitive abilities in a game-like fashion

The game-like nature of the activity involves some competition as a motivating element

Activity Model:

The first player lays out the sequence of cards in an area which the agent can see, but which the other play can't. The agent stores this sequence, and either migrates to another platform close to the other player, or moves to the other player. The second player then lays down a card. The agent gives feedback to the player, depending on whether or not it is correct. If the player fails twice, the agent uses cues to give a hint to the player, suggesting which half of the sequence the cards are meant to be placed.

After the agent has observed a correct placement, or given a hint, it moves to the first player to inform them of this event before returning to the second player.

The game continues until the second player has completed the sequence. The agent offers some form of positive feedback and encouragement and invites the first player to lay down a sequence of cards.

Place/Setting:

This activity is confined to areas where players can be comfortably seated. While it is possibly to play the game in the same area, it is also possible to play the game with each player being in a distant location from the other, using the agent to remotely migrate back and forth.

Artefacts/Media

The cards used in this activity are specially designed to be easily distinguishable by the agent.

The agent needs a platform that can recognise the cards and their position as well as offer feedback to the players.

Time/Flow:

The game is determined by the sequence of actions. The actual length of each game depends on how quickly the second player manages to complete the sequence.

Variants:

The possibility of each player teaching the agent a particular/personalised form of feedback to signal success or failure (e.g. a light flashing, verbal “well done” feedback, playing a tune etc.)

Research Questions include:

- Does Platform/Embodiment of agent impact engagement?
- Agent as gameplayer vs agent as mediator.
- Personalised feedback cues

IV. Teaching Proxemic Preferences

Key Idea:

The user(s) teaches the agent their proxemic preferences in different situations which allows the robot to respect the user’s social spaces

Human-robot relationship:

Robot as socially aware and personalized, adaptive assistant

Actor:

This activity is carried out by one or more users.

Activity Description:

The user teaches the agent about their proxemic preferences in a given situation, using communication methods appropriate for the platform being interacted with. The robot will learn preferences expressed by individual users, and keep a profile of these preferences to be used and further adapted in future encounters.

Motivation for the actor:

For the actor, teaching the agent their proxemic preferences will be beneficial in several ways:

- Reduces the negative impact of the agent in the everyday life
- Increases the perceived efficacy of communicating with the agent, as communication has a tangible, lasting effect.
- Increases feelings of ownership, as the agent’s behaviour becomes personalised.

Activity Model:

The activity is initiated by the user. The user communicates their intention to divulge a proxemic preference, and instructs the agent. This can be done either in absolute terms (i.e. 60 cms away from me) or in relative terms (move away, stop, come closer). The agent will try to comply with these instructions, after which the user may instruct it further, or communicate that this particular distance is appropriate.

The agent will from now on try to comply with this particular distance as a default setting.

The user may later communicate to the agent that a subsequent situation is different and offer new instructions. The agent will then try to generalise the teaching to similar situations.

Variants of this model may be to introduce this scenario as a sub-activity (personalization) in other scenarios. Also, it may be interesting to introduce more than one human user for the system.

Artifacts/Media:

The agent requires an embodiment that allows it some ability to change its position relative to the user, as well as recognise the user and measure the distance to it. The agent will also need to be able to learn preferences for different users/situations and generalise across different situations in order to implement appropriate proxemic behaviour.

Time/Flow:

This activity is conducted on an ad-hoc basis depending on the preferences of the user, as well as in an iterative manner as each instance of the activity refines the agent's knowledge of the users' proxemic preferences.

Research Questions include:

- Development and implementation of proxemics architecture
- Perceptions of robot behaviour
- Interaction Styles (Voice commands, Specialised Gesture Communication)
- Differences between embodiments/platforms(Across different robotic platforms or possibly between computer 3-D representations of proxemic issues and physical embodiment

V. Traveller's companion

Key idea:

A companion agent that can migrate to different devices in different places where user works/lives

Actors/Roles:

One user is involved in this scenario. He/she needs to work in different rooms of her/his house, as well as make visits to local shops or to the office etc. The user prefers his/her personal companion agent to work with and assist.

Activity description:

At the beginning of the activity, the user works in one room and interacts with its companion agent which is in it 'default home' physical embodiment. The second half of the activity involves the user moving to another room of the same apartment/house or to go outside and travel to other places. In this new place, a differently embodied robot is available for the user's companion agent to migrate to. The migrated agent continues to assist the user in a usual way, although the actions that the agent now can perform are enhanced or restricted, depending on the constraints of the "new" agent embodiment.

Motivations for the user:

- Services that the companion provides in one environment will still be available to some extend in another environment with a differently embodied agent

- Continuity of interaction: companion will remember its previous experiences
- Ease of use: user can interact with the ‘same companion’ in a similar way

Activity model:

1. Through a series of initial interaction, the user’s companion remembers his/her preferences in the usual office environment. This stage of the activity may incorporate elements of the activities in scenario 1 and 4.

2. Now the user leaves the room and move to another – In respect to an experimental investigation or showcase demo the user is told during the room moving that he/she has travelled from a place to another for the visiting purpose. So the user has to enter another room and stay there to work for sometime. It is also possible to allow the user "carrying" the companion agent via a laptop/PDA.

3. In the second room, there is a new platform available for the user's companion agent to migrate to. The user can command the agent to migrate (from the carried over laptop/PDA, or just via Internet) to the new platform, or allow the migration process to happen automatically.

4. The companion agent in the new environment performs similar tasks and takes into account individual preferences consistent with previous interactions – in order to facilitate the user’s perception of the devices as platforms for a consistent migrating agent personality.

Artifacts/Media:

Differently embodied robots and PDA/laptop. Embodiments need to be chosen carefully.

Time/Flow:

The length of this activity will depend on how many common interactions the user and the companion agent need to initiate in the first "usual" working environment. The second half of this activity happening in the new environment is mimicking the first environment with a different environmental layout and also a different platform of the agent, so tasks will be carried out not exactly in the same way.

Research Questions include:

- Migration processes
- ‘Smoothness’ of the migration (how well can agent 2 emulate the functionalities of agent 1?)
- User experience
- What are the important cues to provide the user with the perception of a consistent underlying agent across the platforms?