Knowledge Representation for a Neuro-Symbolic Network in Home Care Risk Identification

Qadeer, Nauman; Velik, Rosmarie; Zucker, Gerhard; Boley, Harold

Publisher's version / Version de l'éditeur:

Proceedings of the 7th IEEE International Conference on Industrial Informatics(INDIN 2009), 2009-06-26

Knowledge Representation for a Neuro-Symbolic Network in Home Care Risk Identification

Nauman Qadeer*, Rosemarie Velik*, Gerhard Zucker* and Harold Boley**

**Institute of Computer Technology, Vienna University of Technology, Austria;*
e-mail: {qadeer, velik , zucker} AT ict.tuwien.ac.at

*** Institute for Information Technology, National Research Council Canada, Fredericton, NB, Canada*
e-mail: harold.boley AT nrc.gc.ca

***Abstract*- Risk identification in home care is a key issue in ambient assisted living today. This paper introduces a bionic approach to risk identification in home care based on simple, inexpensive and diverse sensors. Neuro-symbolic perception combines characteristics of neural and symbolic information processing. We represent knowledge relevant for home care as an ontology and apply this knowledge in a neuro-symbolic network to identify risks. A top-level ontology about the assisted living of elderly people is proposed as part of a use case for risk identification in home care.**

***Keywords*- Risk identification, Ambient assisted living, Home care, Neuro-Symbolic Perception, Knowledge Representation, Ontologies.**

I. INTRODUCTION

Classical building automation has generally focused on tasks like the control of lighting and heating, aiming to increase energy efficiency and comfort of the occupants. Today, applications are shifting from these quite simple control tasks to more complex requirements such as the autonomous surveillance of buildings [1]. It is attempted to monitor what is going in a building without the need for a human supervisor who has to take over this – often repetitive – observation task. By such measures the 'external' security and safety can be increased in private and public buildings. Similarly, certain kinds of 'internal' monitoring in hospitals or homes can be beneficial for the ambient assisted living of elderly or handicapped people. In particular, aspects of the health and well-being of occupants can be observed automatically thus supporting medical and nursing staff. Furthermore, elderly and handicapped persons could be enabled to live longer independently in their own homes.

To achieve these new possibilities, buildings have to be equipped with different sensors. As argued in [2], there is a tendency to use an immense number of simple, inexpensive and diverse sensors for such purposes. Classical approaches cannot cope with the task of fusing, merging, and interpreting such a vast amount of diverse information. New methods and information processing principles are needed to handle these demands of the upcoming future. In recent times, research started to focus on bionic principles looking at nature as an archetype [3]. In fact, animals and humans are themselves equipped with millions of sensory receptors. The information coming from these receptors is then efficiently processed in their brains and results in the perception of their environments. Taking these concepts as a basis for the development of technical systems appears to be a very reasonable idea.

One particularly promising bionic approach proposed in the last years is the principle of neuro-symbolic information processing [4]. It is based on neuro-scientific and neuro-psychological research findings about the perceptual system of the human brain and aims to emulate its organizational structure and its information processing principles for the purpose of sensory data processing and interpretation. Basically, sensory information is processed in a so-called neuro-symbolic network with a modular hierarchical structure supported by mechanisms labeled 'knowledge', 'memory' and 'focus of attention'. In this article, we will show how risks can be perceived using knowledge in neuro-symbolic perception applied in elderly home care centers.

In section II, we will give an overview of recent technical developments relevant to homes for elderly or handicapped people. Section III contains an introduction to the neuro-symbolic information processing concept followed by a description of knowledge representation about elderly people through an ontology (section IV). Section V describes the proposed method for identifying risks in elderly home care using the neuro-symbolic perception principle and knowledge ontology of elderly people. Finally, section VI gives a conclusion and points out future work in this field.

978-1-4244-3760-3/09/$25.00 © 2009 IEEE

II. STATE OF THE ART

The techniques proposed here is a first attempt at knowledge representation for neuro-symbolic networks applied to risk identification in home care. However, other techniques have been employed earlier for risk identification in home care.

Reference [5] uses visual cues for risk perception of elderly people. It recognizes the situation and behavior of the persons to estimate risks, and when a risk is estimated high it notifies the person at risk by means of audio and visual cues. Reference [6] shows an approach using artificial agents for the Telehealth Smart Home (TSH) system. This system takes care of an elderly person who suffers from loss of cognitive memory. TSH uses ontologies for describing the domain and Bayesian networks to recognize the patient's activity. Reference [7] presents an ontology-based context model which provides middleware support for flexible event representation using semantic web standards in monitoring and handling agitation behavior for persons with dementia.

III. NEURO-SYMBOLIC PERCEPTION

In order to apply neuro-symbolic perception for home care we will give a short overview of the concept and the foundations it relies on.

A. The Principle of Neuro-symbolic Information Processing

In figure 4, an overview is given about the model of neuro-symbolic information processing. The model is applicable for any type of system which has to combine and interpret a huge number of diverse sensory data. Starting point for data processing are sensor data from different sensory receptors the technical system is equipped with. These data are then processed in a neuro-symbolic network and result in a perception of what is going on. Besides the information coming from sensor data, these perceptions can be influenced by stored knowledge and focus of attention. For the current article, the module of focus of attention is only of minor interest and will therefore not be considered further. For the neuro-symbolic network and the modules memory and knowledge, a description of their function is given in the following.

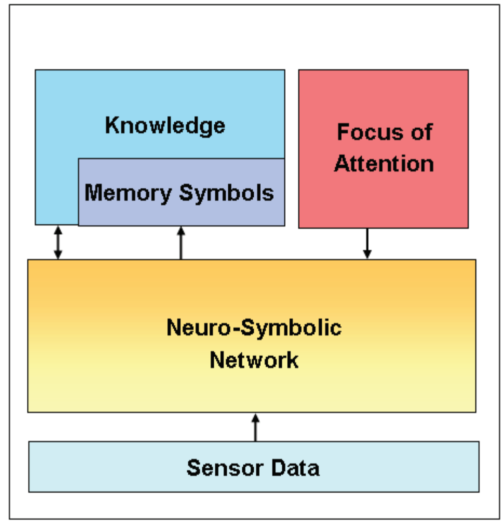


Figure 1: Neuro-symbolic Perception Architecture

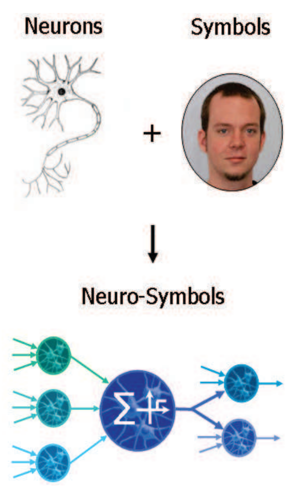


Figure 2: Neuro-symbols

The basic information processing units of the neuro-symbolic network are called neuro-symbols which combine characteristics from neural and symbolic information processing (see figure 1 and 2). The idea for the development of neuro-symbols builds on different assumptions.

Information processing in the brain takes place in form of neural interactions. However, thinking is generally not considered in terms of action potentials and firing nerve cells but in terms of symbols and their interaction with each other. Examples for symbols would be a face, a person, a melody, a voice, and the like. We can regard neural and symbolic information processing as information processing in the brain at two different levels of abstraction. The question that raises now is whether there exists a connection between these two levels. Looking at neuropsychological literature [8, 9], we find reports about neurons in the brain which react for instance exclusively if a face – which can be considered as symbolic information – is perceived in the environment. This allows the conclusion that such an interface between the neural and symbolic level exists and was the motivation for designing neuro-symbols as basic information processing units of the system.

Neuro-symbols represent perceptual images – symbolic information – like a person, a face, a voice, a melody, etc. Neuro-symbols have a so-called activation grade, which indicates whether the perceptual image they represent is currently present in the environment. Neuro-symbols have a certain number of inputs and one output. Via the inputs, information about the activation grade of other neuro-symbols can be received. These activation grades are then summed up and normalized by dividing this sum by the number of inputs of the neuro-symbol. If the normalized sum of a neuro-symbol exceeds a threshold value, the neuro-symbol is activated and information about its activation grade is transmitted via the output to other neuro-symbols.

To process sensory data in an efficient way, neuro-symbols have to be structured to neuro-symbolic networks. The structural organization of neuro-symbolic networks is inspired by the modular hierarchical structure of the perceptual system of the human brain as described by [9] (see figure 3).

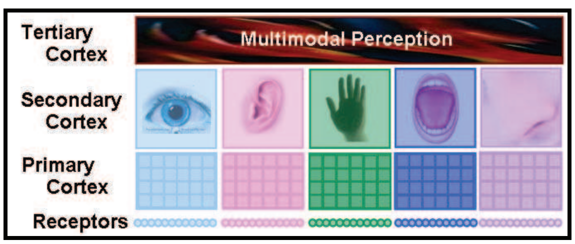


Figure 3: Structural organization of the human perceptive system

Starting point for perception are sensory receptors of the different modalities (visual, acoustic, somato-sensory, gustatory, and olfactory perception). This sensory information is then processed in three levels. In the first two stages, the information of each sensory modality is processed separately and in parallel. In the third level, the information of all sensory modalities is fused and results in a multimodal perception of the environment. In the same way, neuro-symbols are arranged to neuro-symbolic networks (see figure 3).

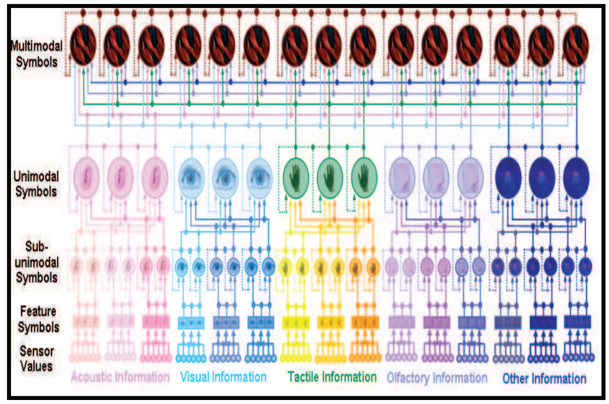


Figure 4: Neuro-symbolic information processing

Again, sensor values are the starting point for information processing. These sensor data are then processed in different hierarchical levels to more and more complex neuro-symbols until they result in a multimodal perception of the environment on the multimodal level, which is also the output level of the system.

B. Memory Symbols

In the neuro-symbolic network, activated neuro-symbols represent what is currently perceived in the environment. If a particular perception disappears, the activation of the corresponding neuro-symbols disappears at the same moment. The neuro-symbolic network itself has no "memory". In the case that it is desired to store information about perceptual images perceived in the past, so-called memory symbols can be used to fulfill this task. Similar like neuro-symbols, memory symbols have an activation grade. They have two inputs and one output. Via one of the two inputs, a memory symbol can be set based on information coming from a certain neuro-symbol. Via the other input, it can be reset again based on information of another particular neuro-symbol.

Memory symbols tightly interact with the knowledge module. In cooperation with this module, they can have feedback influence on the activation of neuro-symbols of the neuro-symbolic network.

C. Knowledge

In the brain, perception does not only rely on sensor data but also on stored knowledge. This knowledge can be:

- Factual (semantic) knowledge like "Objects fall down because of gravity" or "Vienna is the capital of Austria".
- Context knowledge like certain objects, events and situations always occur at a certain place or at a certain time.

• Expectation knowledge like certain objects, events and situations generally occur after particular other objects, events and situations.

In the model of neuro-symbolic information processing, stored knowledge can interact with the neuro-symbolic network and increase/decrease or inhibit the activation of certain neuro-symbols.

In this paper, we focus on the knowledge related to elderly people in order to identify risks using this neuro-symbolic perception principle. A more detailed description, about how this works, is given in the next section.

IV. REPRESENTING HOME CARE KNOWLEDGE

Our main knowledge representation is a light-weight ontology classifying relevant concepts of the home care domain as a taxonomy which also provides the backbone for a vocabulary of important properties (binary relations). We exemplify this representation with home care knowledge about elderly people, proposing an initial top-level ontology as depicted in figure 5.

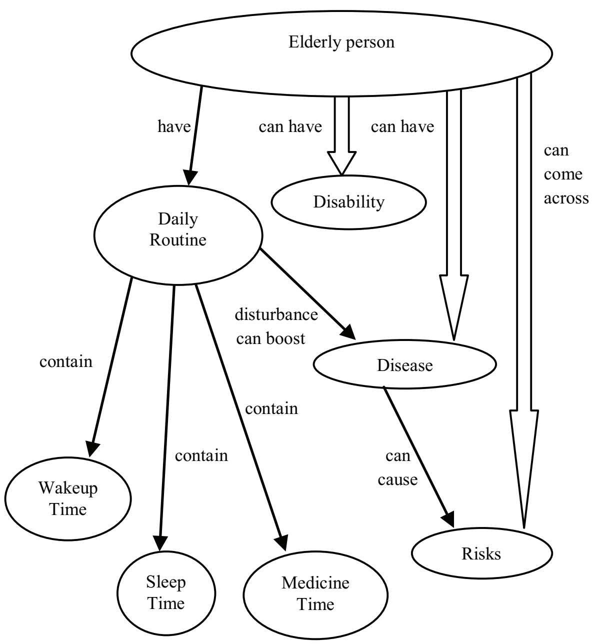
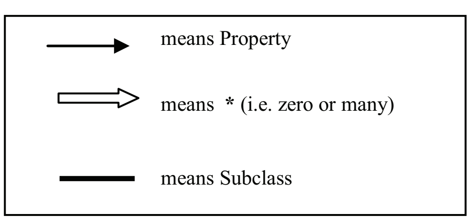


Figure 5: Ontology to represent knowledge about elderly person in an elderly care center



Each elderly person has a daily routine which includes his/her time for waking up, sleeping and taking medicine. A disturbance of routines can increase certain risks. For example, if a person of hyper-tension has not taken his/her medicine on time or has any disturbance in sleep then he/she can feel dizzy and hence has a higher risk to collapse. Such factors have to be considered while identifying risks based on sensor values. For example, if through video cameras it is detected that a person is in a lying position on the floor then this could mean that he/she is doing some exercise. But here the medical history of the patient – stored as context knowledge about that person – can help to decide whether he/she has fallen down and needs help or is just exercising. If it is also found that he/she had not taken medicine in time then there is a high probability that the person fell down.

Elderly persons may be suffering from one or many diseases or disabilities. Common disabilities in elderly persons include speech, auditory, visual or motor aspects as depicted in figure 6.

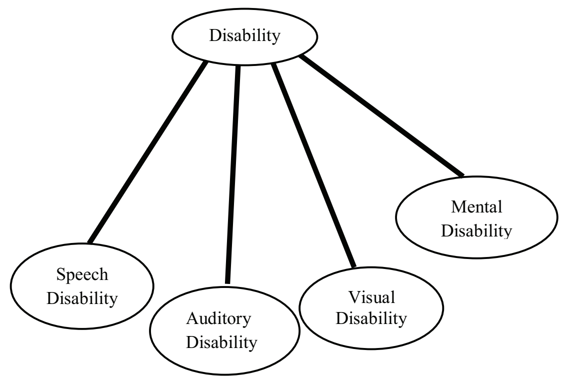


Figure 6: Ontology of some common disabilities in elderly people

Common diseases in elderly persons are shown in figure 7.

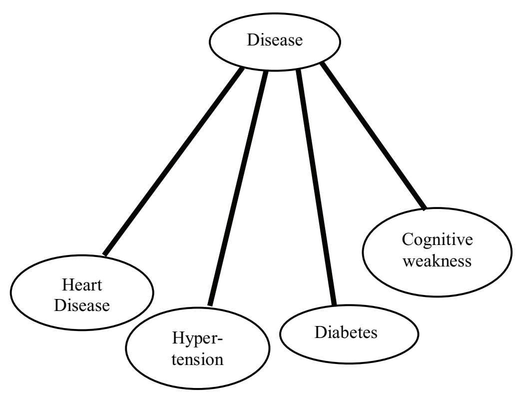


Figure 7: Ontology of some common diseases in elderly persons

Possible risks that can occur in elderly home care centers are represented by the initial risks ontology in figure 8.

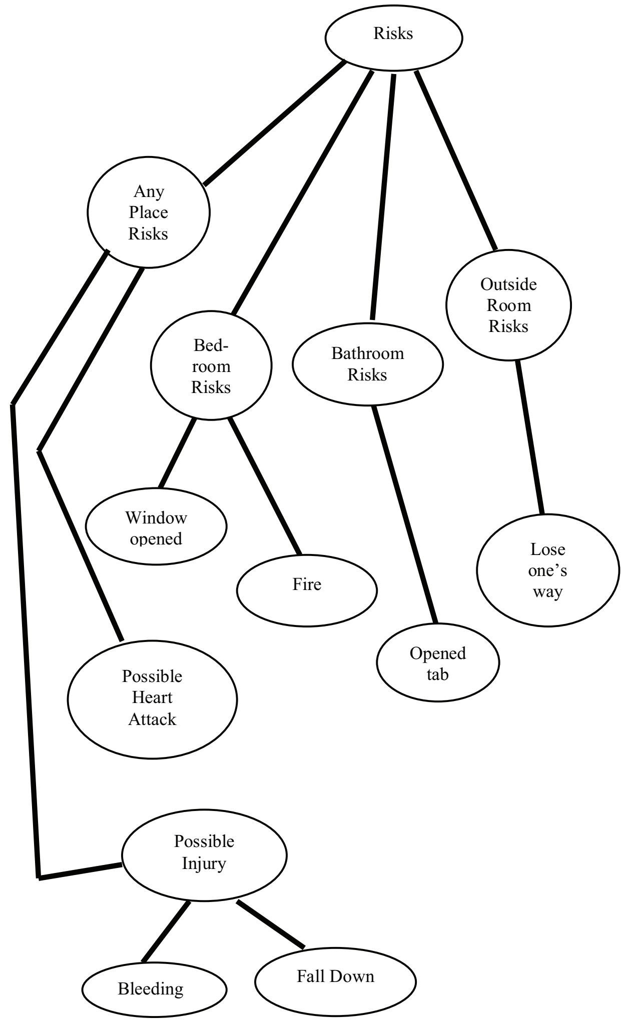


Figure 8: Ontology of some common risks in elderly home care

V. RISK IDENTIFICATION METHOD

As mentioned in section III, the starting point for neuro-symbolic architectures is sensory data. There may be different sensors (microphones, video cameras, tactile sensors, touch sensors on windows and doors, temperature and smoke sensors) in elderly home care centers for monitoring elderly people. Common risks that can occur in such centers were represented taxonomically in the last section. These risks are now represented by neuro-symbols at the final (upmost) level of the neuro-symbolic network. Some of the risks are particular to a place while others can occur at any place. For example, elderly persons having mental disabilities may forget to close the window in winter. By observing that the room temperature is rapidly decreasing, it can be perceived that a window remained opened. This risk appears to be particularly high in a bedroom. Similarly, such a person can forget to close the tab of the bathroom. When a person with a mental disability leaves his/her room and moves towards the main door of the center then he/she may exit from the center, which can have severe risks, e.g. that he/she might forget the way back to the center. This risk is perceived using our neuro-symbolic perception method as demonstrated in figure 9. For the sake of simplicity, only those neuro-symbols are depicted that are related to this example.

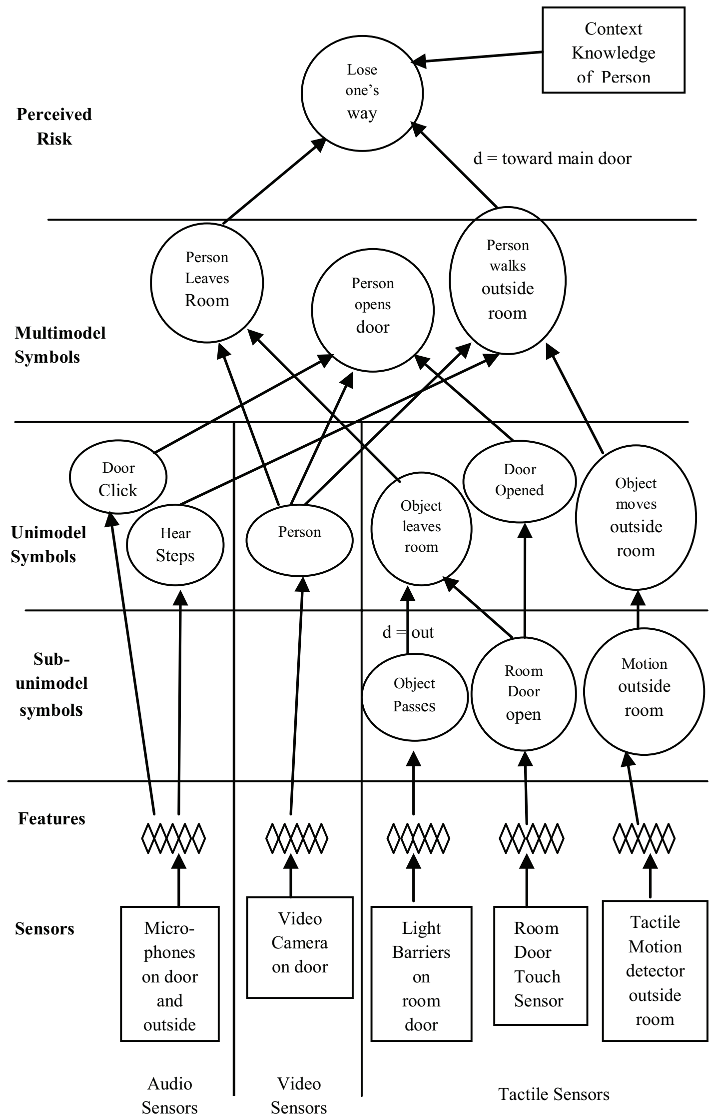


Figure 9: Identifying Risk "Lose one's way"

When an elderly person opens the door of his/her room, the touch sensor of his/her room door reacts and light barriers on the room door show the passage of some object. By observing that the direction (d) of the object is outside, it can be derived that the object is leaving the room. Furthermore, through video sensors, the person can be identified and for this purpose image recognition algorithms can be used. At the multi-modal level, it can be concluded that the person is leaving the room. This means that a neuro-symbol is activated that represents "person leaves room". When the person comes out of the room then tactile sensors on the floor can tell about his/her direction, and if his/her direction is towards the main exit of the center then context knowledge about this person is consulted, which represents that he/she is suffering from mental disability. This knowledge acts as a feedback on the neuro-symbolic network, hence helps triggering the neuro-symbol for the risk of "Lose one's way".

VI. CONCLUSION AND FUTURE WORK

In this paper a new method is introduced for identifying possible risks in elderly home care centers. This method aims at using a bionic approach to perception. An ontology is proposed for representing knowledge relevant to elderly people living in care centers. Based on this ontology, several risks are discussed. These risks are then represented as neuro-symbols at the final level of a neuro-symbolic network. A home care use case is described to show how these risks are identified using context and expectation knowledge in neuro-symbolic perception. In future, research will be done to extend and formalize these knowledge representation models and to refine the interface between the neuro-symbolic network and the knowledge module so that this neuro-symbolic architecture can be generalized and used in different domains.

REFERENCES

[1] Velik, R., A Model for Multimodal Humanlike Perception based on Modular Hierarchical Symbolic Information processing, Knowledge Integration and Learning. In Bionetics' 07, December 10-13 2007, Budapest, Hungary.

[2] D. Dietrich, T. Sauter, Evolution potentials for fieldbus systems, Proceedings of the IEEE International Workshop on Factory Communication Systems, (2000), p. 343 - 350

[3] R. Velik, R. Lang, D. Bruckner, T. Deutsch, Emulating the Perceptual System of the Brain for the Purpose of Sensor Fusion, Proceedings of the 2008 IEEE Conference on Human System Interaction (HSI), (2008)

[4] Velik, R. (2008). A Bionic Model for Human-like Machine Perception. PhD thesis, Vienna University of Technology.

[5] Kanai, H., Tsuruma G., Nakada, T., Kunifuji S., Notification of Dangerous Situations for Elderly People using Visual Cues. In IUI' 08, January 13-16, 2008, Maspalomas, Gran Canaria, Spain.

[6] Latifi, F., Lefebvre, B., Descheneaux, C., Ontology-Based Management of the Telehealth Smart Home, Dedicated to Elderly in Loss of Cognitive Autonomy 2007
http://www.webont.org/owled/2007/PapersPDF/submission37.pdf

[7] Fook, V., Tay, S., Jayachandran, M., Biswas, J., Zhang, D. An Ontology-based Context Model in Monitoring and Handling Agitation Behaviour for Persons with Dementia. Proceedings of the Fourth Annual IEEE international conference on Pervasive Computing and Communications Workshops (PERCOMW' 06).

[8] Goldstein EB (2002) Wahrnehmungspsychologie. Spektrum Akademischer Verlag.

[9] Luria R (1973) The Working Brain - An Introduction in Neuropsychology. Basic Books.