The possible contribution of the amygdala to memory

R. Babinsky1,4, P. Calabrese1,2, H.F. Durwen2, H.J. Markowitsch1, D. Brechtelsbauer2,3, L. Heuser3 and W. Gehlen2

1 Physiological Psychology, University of Bielefeld, D-33501 Bielefeld, Germany,
2 University Clinic of Neurology, and 3 University Clinic of Radiology,
Knappschaftskrankenhaus Bochum-Langendreer, D-44892 Bochum, Germany, and
4 Neurology Department, Kamillus-Clinic, D-53563 Asbach, Germany

Correspondence to: R. Babinsky, Neurology Department, Kamillus-Clinic, D-53563
Asbach, Germany

The processing of episodic memories is believed to depend on the proper functioning of so-called bottleneck structures through which information apparently must pass in order to be stored long term. These regions are seen in the basal forebrain, the medial diencephalon, and the medial temporal lobe. We here report a case with circumscribed bilateral temporal lobe damage, principally involving the amygdaloid area. Neuropsychological investigation demonstrated preserved intelligence, intact general memory and several other undisturbed cognitive functions, but a specific, affect-related, memory disorder. We conclude from these findings that the role of the amygdala is to process mnemonic events in a way that a specific emotional significance can be found and reactivated. Therefore it is suggested that the amygdala is likely to be a bottleneck structure for affect-related long-term memory functions.

Keywords: Affect – Amygdala – Emotion – Information processing – Memory

The importance of the amygdaloid complex for long-term information processing has been an area of debate for many years. This started with the early work of Scoville and Milner (1957) who underemphasized the contribution of the amygdala in amnesia observed in cases after bilateral medial temporal lobe resections by arguing that “it is not known whether the amygdala plays any part in this mechanism [memory], since the hippocampal complex has not been removed alone, but always together with uncus and amygdala” (p. 21). The failure of early investigations to confirm an intimate relationship between medial temporal lobe damage and amnesia in non-human primates was attributed to the tasks used or to interspecies differences (Iversen, 1976; Weiskrantz, 1982). Mishkin (1978), who used a delayed non-match to sample task, demonstrated a severe memory deficit with combined, but not by separate lesions of amygdala and hippocampus. This result was confirmed in other studies (Zola-Morgan et al., 1982; Murray and Mishkin, 1985), but later Squire and Zola-Morgan (1991) questioned the view that the amygdala is important for mnemonic processing. Doty (1990) has also criticized the unreflected transfer of animal results onto those of human beings by, for example, arguing that H.M., Scoville and Milner’s (1957) most famous amnesic, did not show any deficits in the tasks in which the monkeys of Mishkin (1978) had been severely disturbed (Freed et al., 1987). Lastly, in this sequence on evidence for and against the role of the amygdala in memory, Tranel and Hyman (1990) described the case of a young patient with selective bilateral amygdala damage and “a significant defect in visual, nonverbal memory” (p. 354). The authors concluded that their case “is consistent with the position that the amygdala is a crucial component of the neural substrate of memory in humans” (p. 355).

Views on the contribution of an individual brain structure to (long-term) memory processing are critically dependent on (a) the measurements or test procedures applied, and (b) the underlying Weltanschauung one has about the brain’s functioning in information processing. Furthermore, a distinction may be made between “a neuronal system which is involved in memory processing and a system which affects memory processes” (Gold et al., 1975, p. 104). We will comment on variables (a) and (b).

(a) For the amygdala as a strong relay of emotionally (affective) weighted information, the significance and rel-
evance of learning on the individual’s subjective feeling may be a crucial determinant for its involvement. Tasks with “standard” associations will consequently depend much less on the amygdala’s filtering and selection processes than emotionally colorful ones. Furthermore, Tranel and Hyman (1990) hypothesized that it may have a more crucial role in non-verbal, visuospatial memory than in verbal memory. Whether one sees the mechanism of encoding as dependent on a largely hierarchically arranged array of individually active structures, or whether one adheres to a more dynamic view involving multiple interwoven and interacting nets (with still some crucial “bottleneck structures” existing), of cause, largely determines the conclusions one will draw from brain damage-behavior relations.

The appearance of selective bilateral amygdaloid damage in human cases is rare. We found it in a 39-year-old female patient suffering from Urbach-Wiethe disease (lipoid proteinosis), an uncommon, hereditary, systemic disorder characterized by the deposition of hyaline material in the skin and mouth-larynx areas. As is not uncommon in patients with this disease (Emsley and Paster, 1985; Newton et al., 1971), our patient had in addition a mineralization in the medial temporal lobe region which was bilaterally confined to the amygdaloid region, as has been found in previous cases (Fig. 1). In addition to neurological and neuroradiological assessment, the patient was examined neuropsychologically. These tests (described in more detail in Markowitsch et al., 1993) assessed attention and concentration, intelligence, learning, short- and long-term memory, verbal and figural-spatial memory, retrograde memory, concept formation, cognitive flexibility, and affect. A number of tests revealed normal functions, including those evaluating attention (Concentration-Endurance Test d2; Brickenkamp, 1981), concentration (Trail Making Test), intelligence (IQ = 109; reduced Wechsler Adult Intelligence Test; Dahl, 1986), digit span (7), the Corsi block tapping test (4), a German language form of the Rivermead Behavioral Memory Test (Wilson et al., 1985), the revised Wechsler Memory Scale (General Memory = 130, Delayed Recall = 132; Wechsler, 1987), copy and recall condition of the Rey-Osterrieth Figure (copy = 36/36, 100th percentile; 30-min recall = 23/36, 50th percentile; Lezak, 1983), the Wisconsin Card Sorting Test (11 categories, no errors at all), the Tower of Hanoi test with four discs (24 moves, no errors), the Concept Comprehension Task (concrete = 8/8, abstract 7/8; Cronin-Golomb, 1986), and the Gollin Incomplete Pic-
The recent emphasis on the cholinergic system as relevant in declarative information (Forstl and Sahakian, 1993) has identified a bottleneck structure-of which the amygdala is one-filtering out information of different relevance to the individual. This mechanism makes the amygdala a nodal point in the circuitry of the brain implicated in long-term information processing. It underlines the view that certain bottleneck structures—of which the amygdala is one—are involved in a concerted and integrated way in memorizing declarative information. Forstl and Sahakian (1993) have emphasized the cholinergic system as relevant in this respect, assuming the existence of a network composed of the basal forebrain, the amygdala and the orbitofrontal cortex.

Acknowledgement
While carrying out this study, R. Babinsky was supported by KOGNET/Ruhr-University Bochum.

REFERENCES


(Received 30 July 1993; accepted 10 August 1993)