Ch 10. Emotional Learning and Memory

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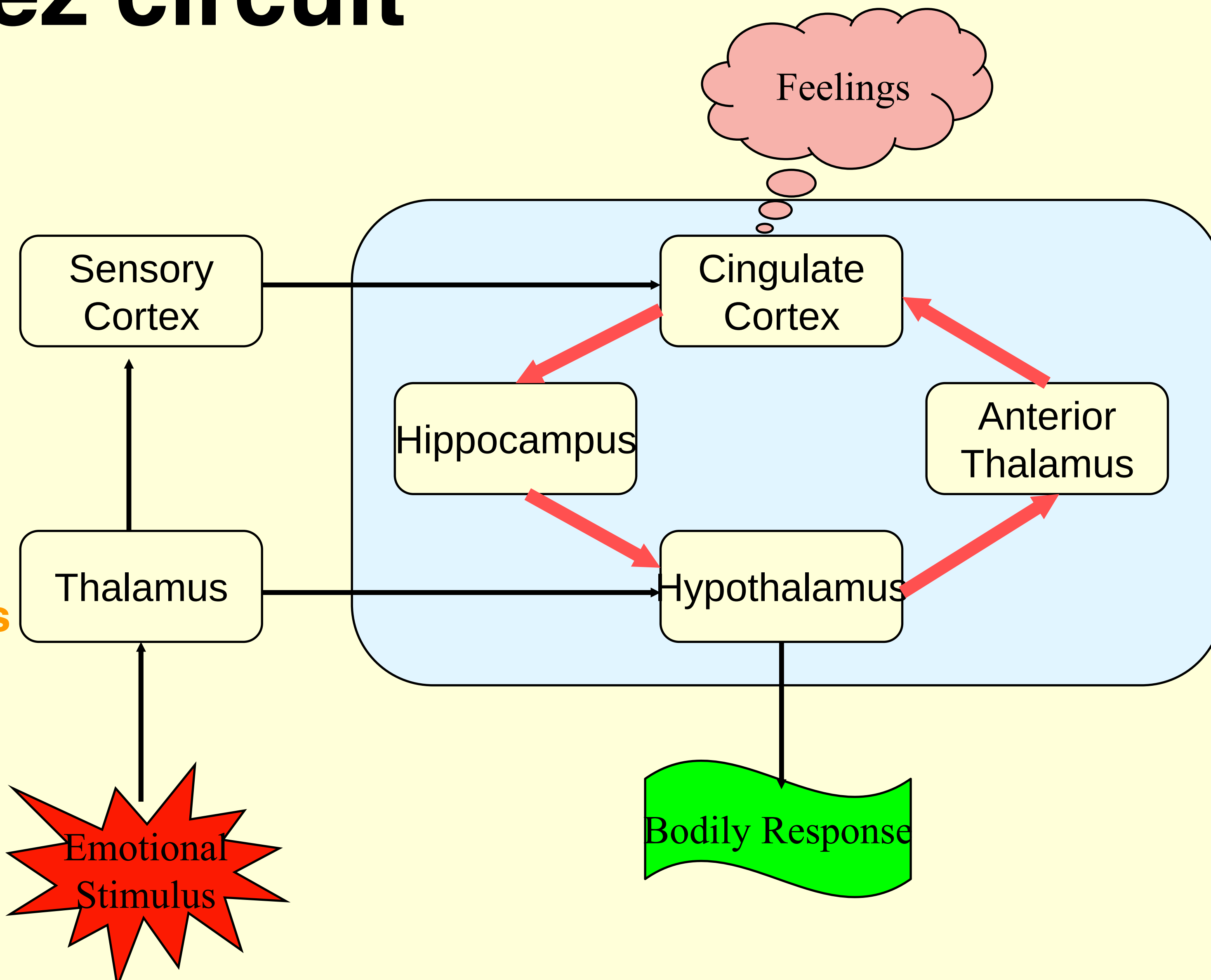
Monday, Dec 3, 2007

today's road map

- what is the Papez circuit?
- what is the limbic system?
- classical fear conditioning
- two routes for emotional learning: cortical and subcortical
- the amygdala
- relation between the emotional memory system and the declarative memory system
- two dimensions: valence and arousal
- what ***cognitive*** processes underlie the recollective memory enhancement for emotional information?
- what ***neural*** processes underlie the recollective memory enhancement for emotional information?

Papez circuit

- hippocampal formation
- mammillary bodies
- anterior thalamus
- cingulate cortex
- parahippo-campal gyrus
- hippocampal formation



Papez, James W. (1937) A proposed mechanism of emotion. *Arch Neurol Psychiat*, *38*, 725.

limbic system

- hippocampal formation
- amygdala (McLean)
- cingulate gyrus
- thalamus and hypothalamus

Broca, Paul (1878) Anatomie comparée des circonvolutions cérébrales. Le grand lobe limbique et la scissure limbique dans la série des mammifères. *Rev. d'Anthrop*, ser 2, *1*, 285.

MacLean, Paul D. (1952) Some psychiatric implications of physiological studies on frontotemporal portion of limbic system (visceral brain). *Electroencephalogr Clin Neurophysiol*, *4*, 407.

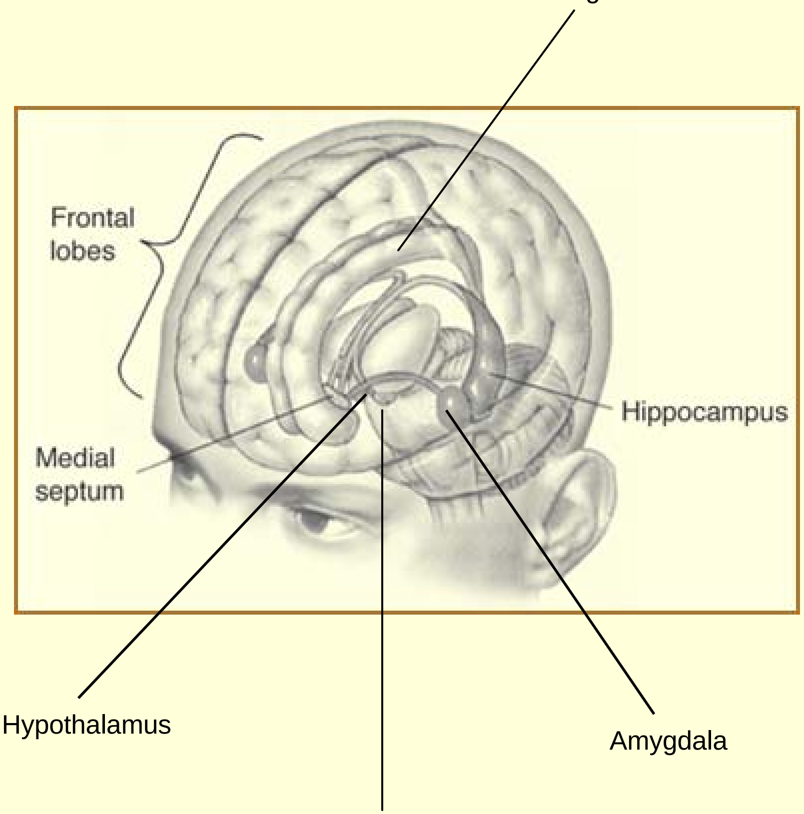


Image courtesy of the NIH.

classical fear conditioning

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left: rat hears a sound, which has little effect on BP or movement
center: rat hears same sound, coupled with foot shock; after several pairings, BP rises and rat freezes when it hears the sound
right: rat has been fear conditioned; sound alone achieves the same physiological changes as did sound and shock together

LeDoux, 1994

what are the cerebral roots of fear learning?

- is auditory cortex required for auditory fear conditioning? ***no***
- what about auditory thalamus? ***yes***
- what about the auditory midbrain? ***yes***
- What about the hippocampus? ***no***

Images removed due to copyright restrictions.
Illustration of rat brain with areas highlighted: auditory cortex, hippocampus, auditory thalamus, and amygdala.

LeDoux, 1994

brain lesions have been crucial in pinpointing the sites that mediate experiencing and learning about fear

Images removed due to copyright restrictions.

The auditory pathway in the rat brain consists of sound entering the ear and being turned into an electrical signal that travels down the auditory nerve to the auditory midbrain, to the auditory thalamus, and finally to the auditory cortex.

If a lesion is made in the auditory midbrain or auditory thalamus, fear conditioning is disrupted. If the lesion is made in the auditory cortex, however, conditioning is not disrupted. These findings imply that the fear conditioning pathway involves the auditory midbrain and auditory thalamus, but not the auditory cortex. The pathway may involve additional, unknown structures.

LeDoux, 1994

auditory cortex is *not* needed to establish simple fear conditioning

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LeDoux, 1994

BUT it *is* needed to interpret stimuli when they become more intricate

- one of two stimuli was paired with foot shock
- intact rabbits expressed fear responses only to the sound that had been coupled with the shock
- after receiving auditory cortex lesions, however, they responded to both tones
- that is, when auditory cortex was absent, and animals had to rely solely on the thalamus and amygdala for learning, the two stimuli were indistinguishable
- **conclusion**: projections to the amygdala from sensory regions of the cortex (e.g., auditory cortex) are important in processing the emotional significance of **complex** stimuli

LeDoux, 1994

anatomy of emotion

- cells in some regions of the auditory thalamus give rise to fibers that reach several subcortical locations
- could these neural projections be the connections through which the stimulus elicits the response we identify with fear?
- researchers made lesions in each of the subcortical regions with which these fibers connect
- the damage had an effect in only one area:

LeDoux, 1994

the amygdala

certain parts of the thalamus (top - light pink) communicate with areas in the amygdala (bottom - light yellow) that process the fear-causing sound stimuli

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LeDoux, 1994

structure of the amygdala

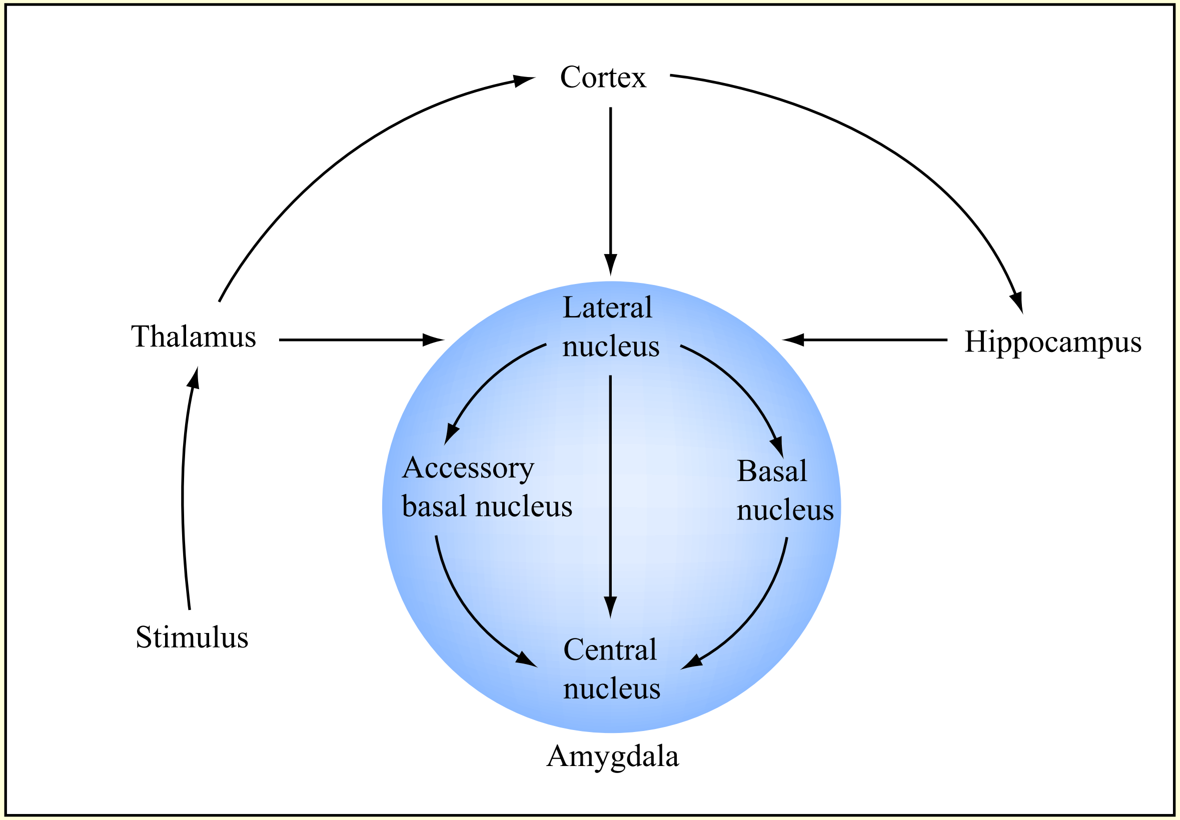


Figure by MIT OpenCourseWare.

lateral nucleus: receives input from sensory regions of the brain and transmits these signals to the basolateral, accessory basal, and central nuclei

central nucleus: connects to the brain stem, bringing about the physiological changes

LeDoux, 1994

Image removed due to copyright restrictions.

Illustration of the intrinsic connections in the lateral nucleus of the amygdala.
See figure in Pitkanen, A., and D.G. Amaral. "Organization of the Intrinsic Connections of the Monkey and Amygdaloid Complex: Projections Originating in the Lateral Nucleus." *J Comp Neurol* 398 (1998): 431-458.

Pitkanen & Amaral, 1998

neurochemical markers in the amygdala

- Glutamate
- NMDA/AMPA
- Glutamine
- GAD/GABA
- Parvalbumin
- Calbindin
- Aspartate
- Histimine
- Dopamine
- Norepinephrine
- Epinephrine
- Serotonin
- AChE
- ChAT
- Somatostatin
- Vasopressin
- CRF
- NGF
- Cholecystokinin
- Neuropeptide Y
- Neurphysin
- Estrogen
- Neurotensin
- Substance P
- VIP
- Enkephalin
- Dynorphin
- Protein kinase C
- Benzodiazepene receptors

Stefanacci, 2???

Connections of the Amygdaloid Complex

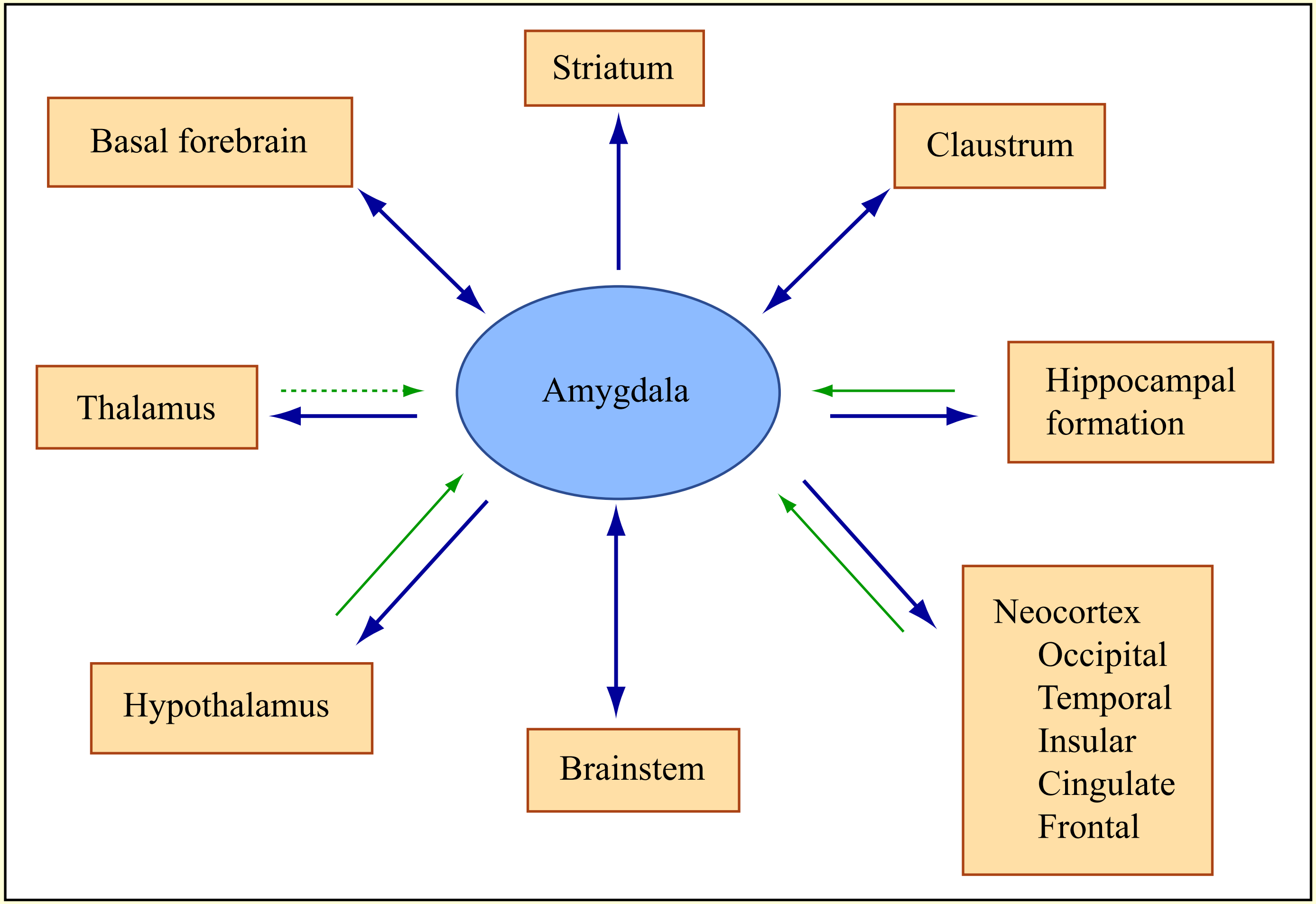


Figure by MIT OpenCourseWare.

Amaral

more evidence that the amygdala supports emotional memory

Image removed due to copyright restrictions.
MRI image of a human brain, with the amygdala highlighted.

- cells in the amygdala fire during encoding of emotional information
- the magnitude of this activation correlates with likelihood of later retrieving emotional information

patients with amygdalar damage show a blunted memory enhancement effect

two routes for emotional learning: one cortical and one subcortical

Image removed due to copyright restrictions.

The cortical route for emotional learning involves input from the senses - for example, a visual stimulus - that travels to the visual thalamus, to the visual cortex, to the amygdala. The subcortical route bypasses the visual cortex, with the signal travelling to the visual thalamus and then straight to the amygdala.

LeDoux, 1994

the amygdala is not the only learning center

- the establishment of memories is a function of an entire network
- what about the hippocampus?
  - important when learning and remembering are conscious events (i.e., declarative memory)
  - removal of the hippocampus in rats has little effect on fear conditioning, but this is not declarative learning (i.e., independent of conscious awareness)
  - emotional information may be stored within declarative memory, but it is kept there as a cold declarative fact

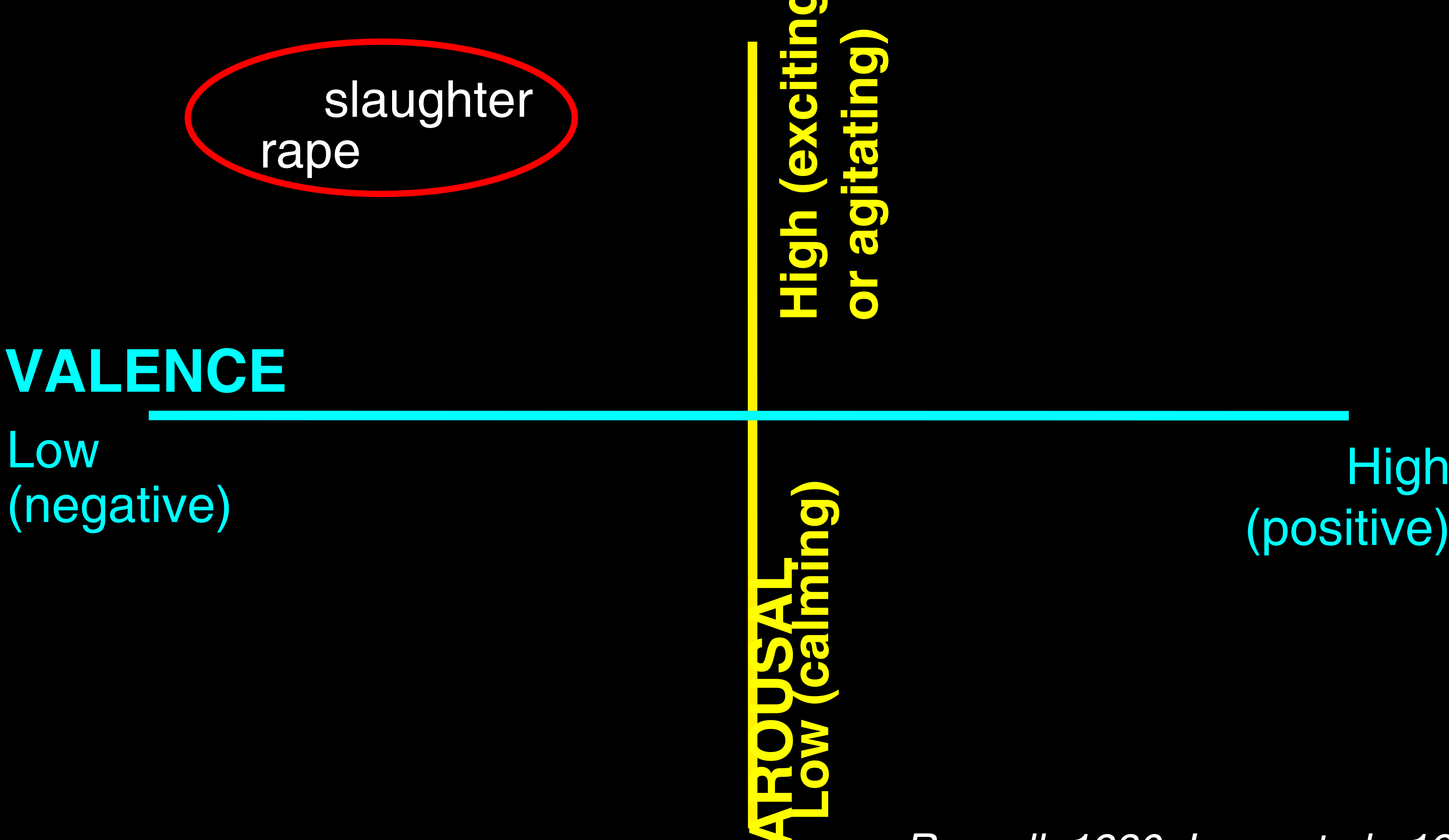
LeDoux, 1994

relation between the emotional memory system and the declarative memory system

- emotional and declarative memories are stored and retrieved in parallel
- their activities are joined seamlessly in our conscious experience
- but that does not mean that we have direct conscious access to emotional memory
- it means that we have access to the consequences (i.e., the way we behave and the way our bodies feel)
- emotion exerts a powerful influence on declarative memory
- the amygdala plays an essential role in modulating the storage and strength of declarative memories

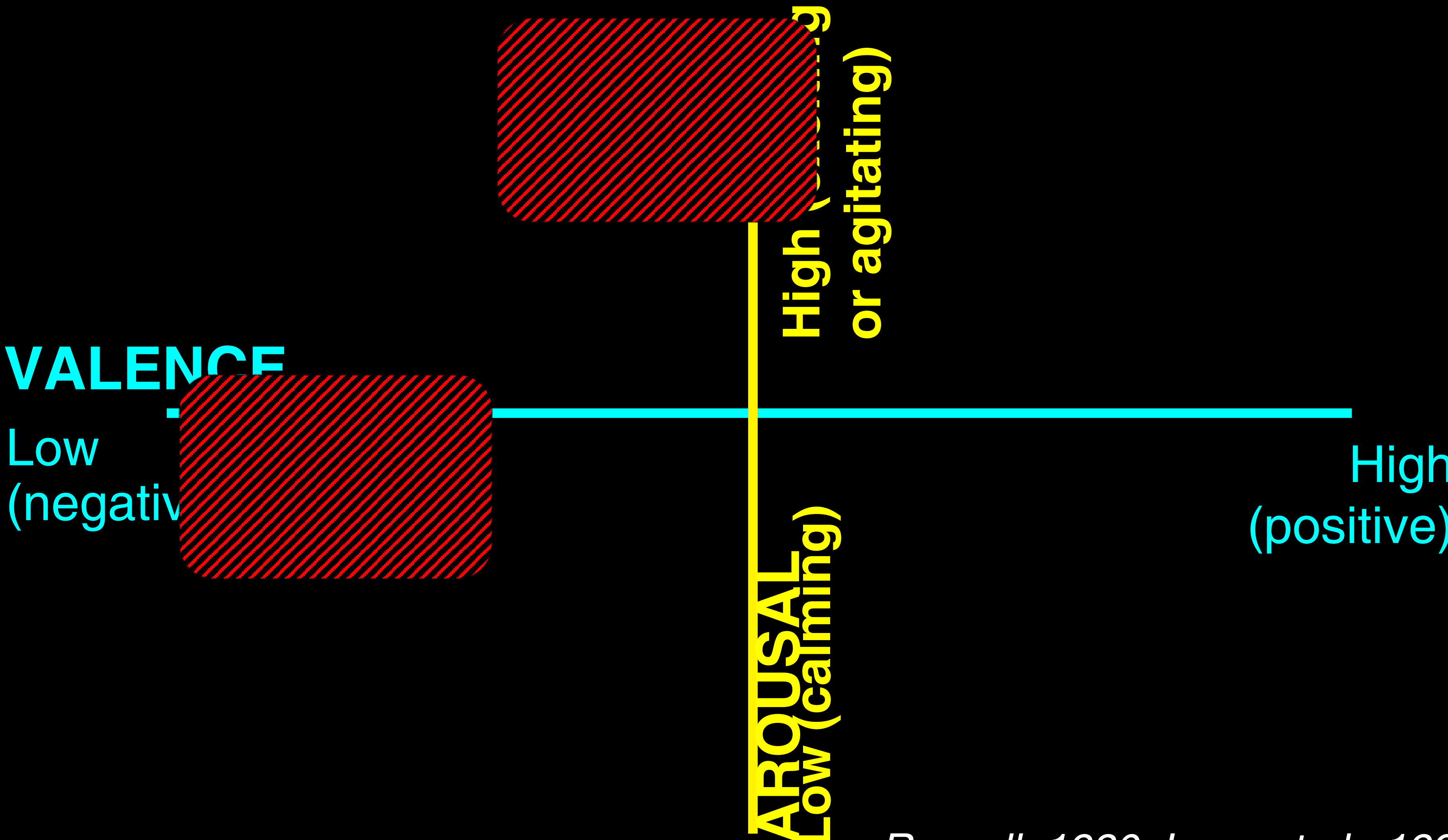
LeDoux, 1994

emotional items differ from neutral items along 2 dimensions: *valence* (negative or positive) & *arousal* (calming or exciting)



Russell, 1980; Lang et al., 1993

some items differed from the neutral ones primarily in *valence*, and others differed primarily in *arousal*



Russell, 1980; Lang et al., 1993

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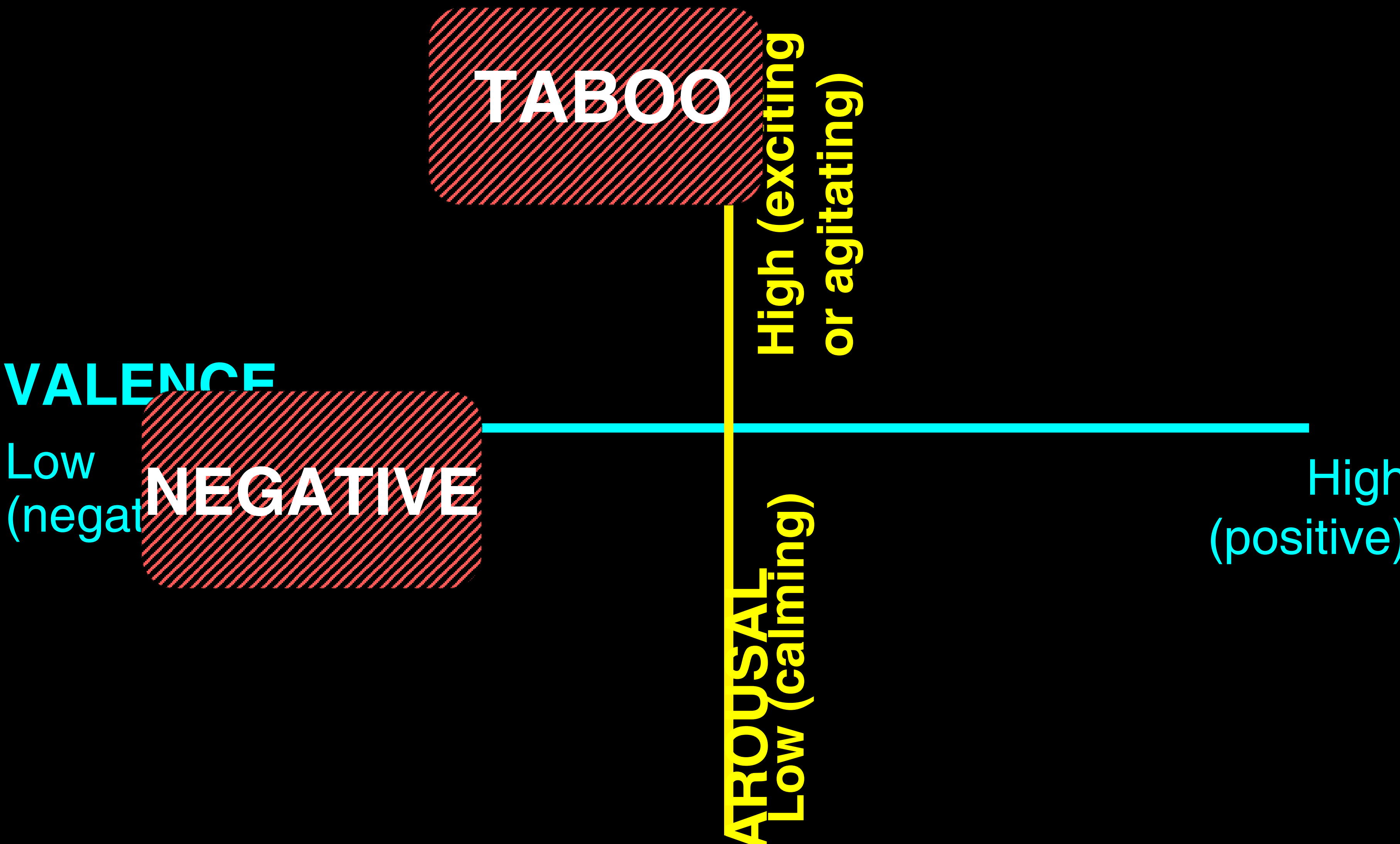
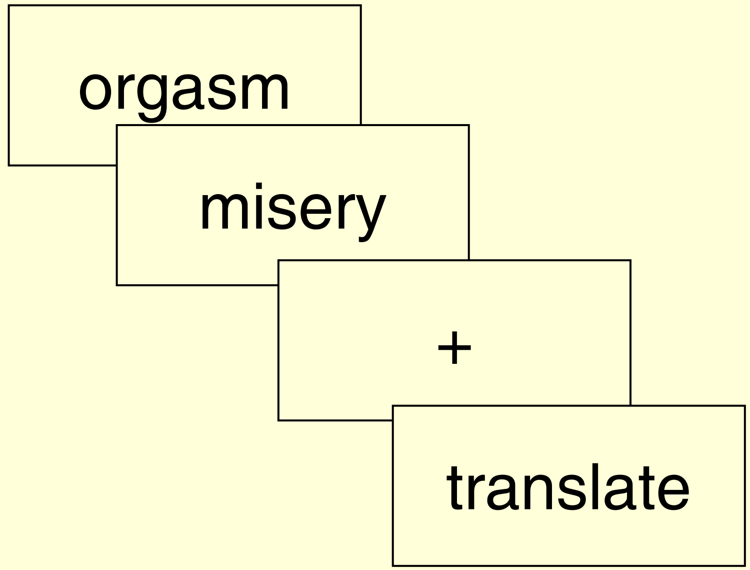


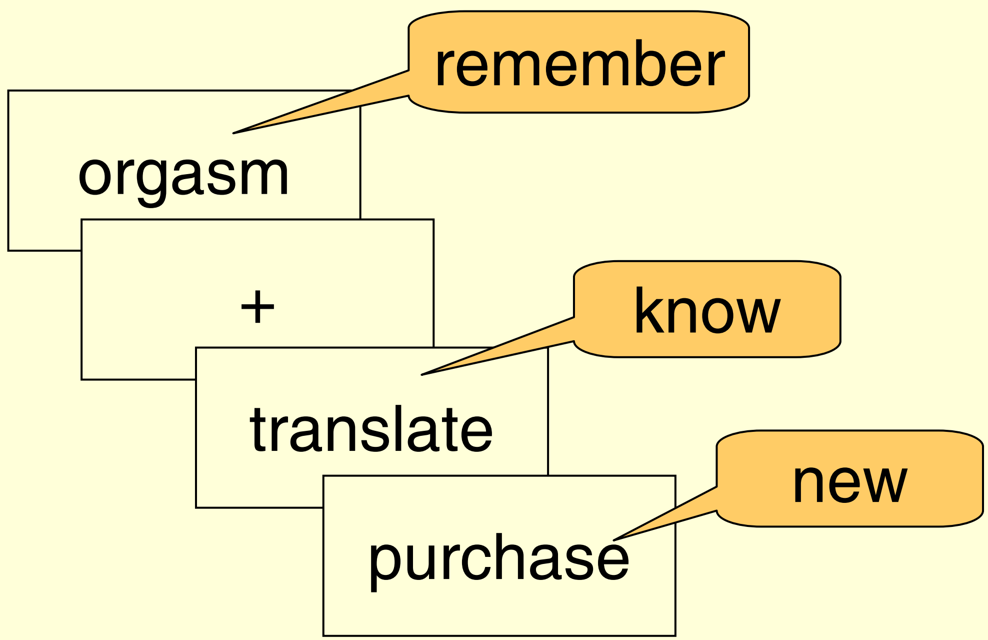
Russell, 1980; Lang et al., 1993

study



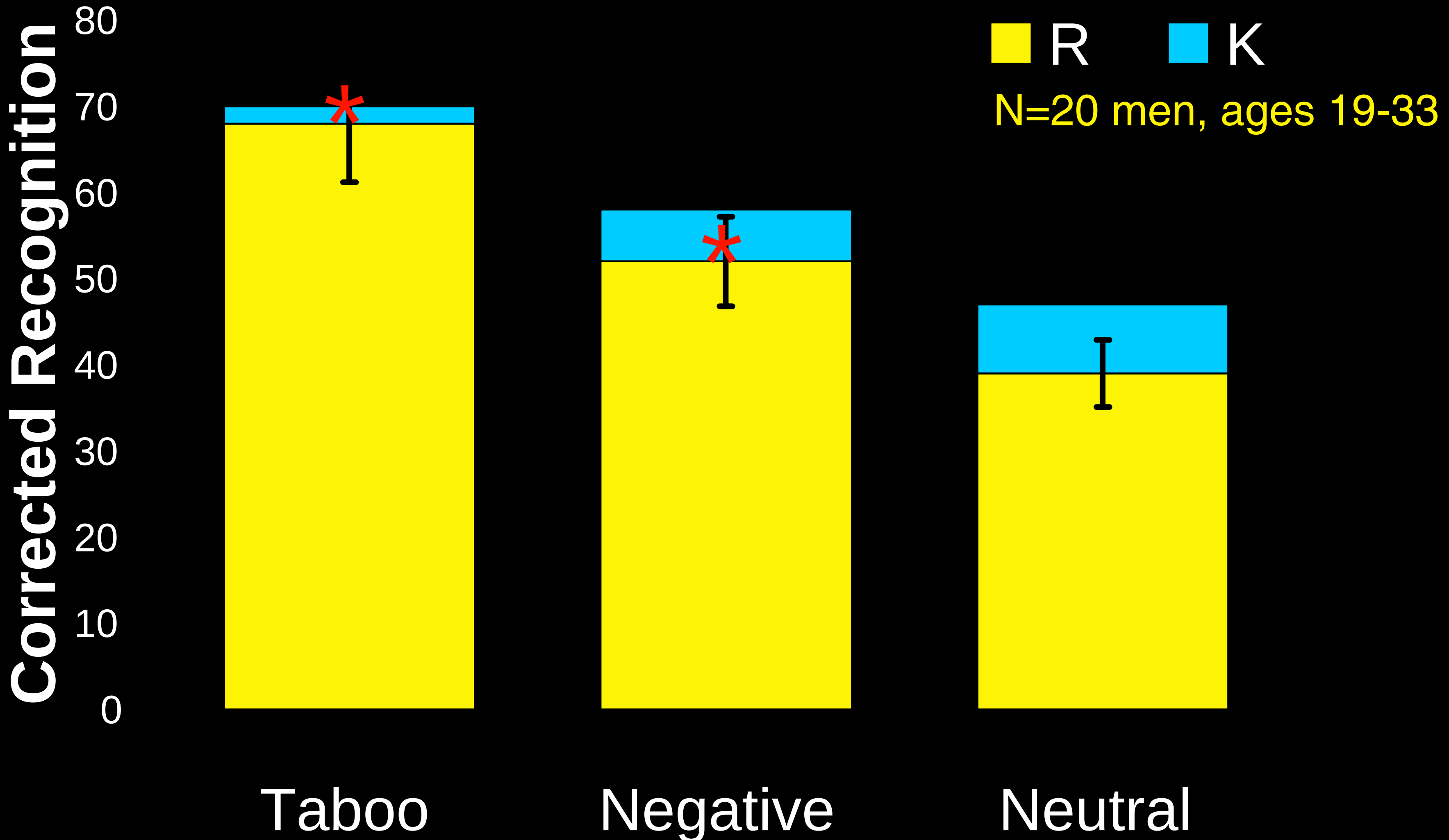
orgasm
misery
+
translate

test



remember
orgasm
+
know
translate
new
purchase

participants are more likely to "*Remember*" valence (negative) than neutral words, and even more likely to "*Remember*" high-arousal (taboo) words



Kensinger & Corkin, 2003, Memory & Cognition

what *cognitive* processes underlie memory enhancement for negative, emotional information?

- participants remember the negative words better than the neutral words because negative emotion
  - ↑ increases the subjective richness of memories, and
  - ↑ increases the contextual details associated with those memories

- memory enhancement is stronger for arousing (taboo) words than for non-arousing valence (negative) words

what *cognitive* processes underlie the recollective memory enhancement for emotional information?

CONTROLLED (self-initiated)

- intentional, conscious
- attention-demanding

OR

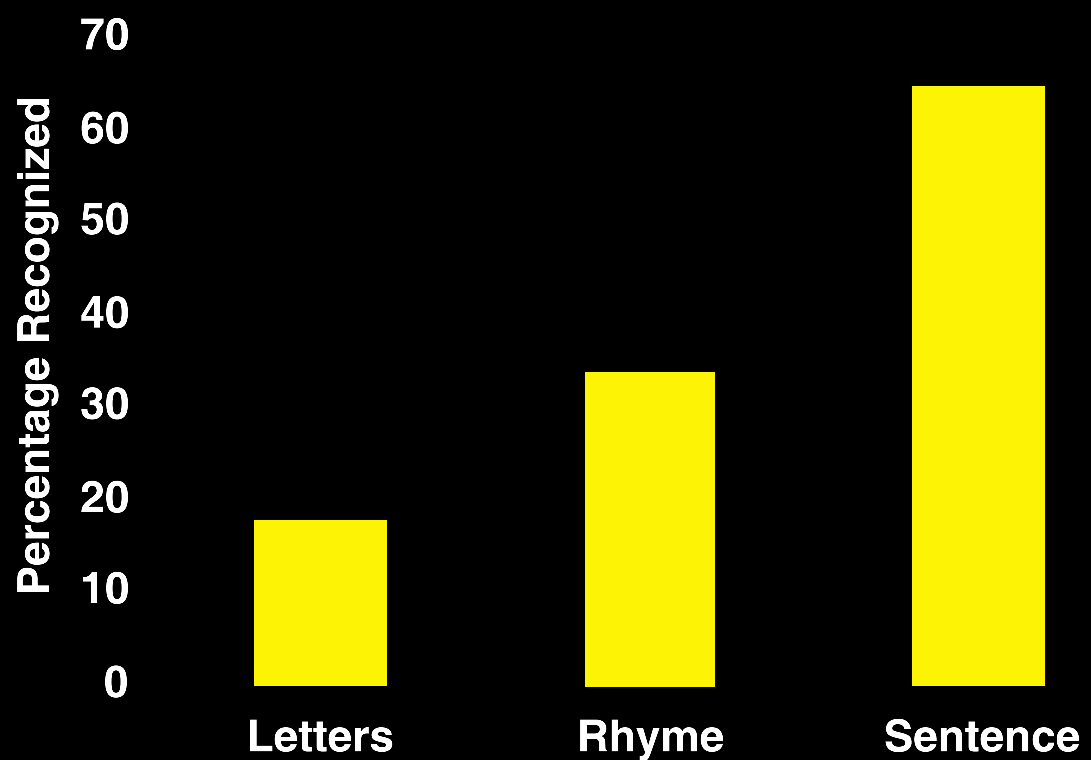
AUTOMATIC

- incidental, not conscious
- not attention-demanding

elaborative encoding benefits memory

- is the word in capital letters?
- does the word rhyme with "pet"?
- would the word fit in the sentence "He met a ______ on the street."

Craik & Lockhart, 1975



- **negative emotional information could be remembered better because of controlled, self-initiated processing**

what *cognitive* processes underlie the recollective memory enhancement for emotional information?

CONTROLLED (self-initiated)		AUTOMATIC
• intentional, conscious • attention-demanding	OR	• incidental, not conscious • not attention-demanding

relatively automatic and/or prioritized processing of emotion

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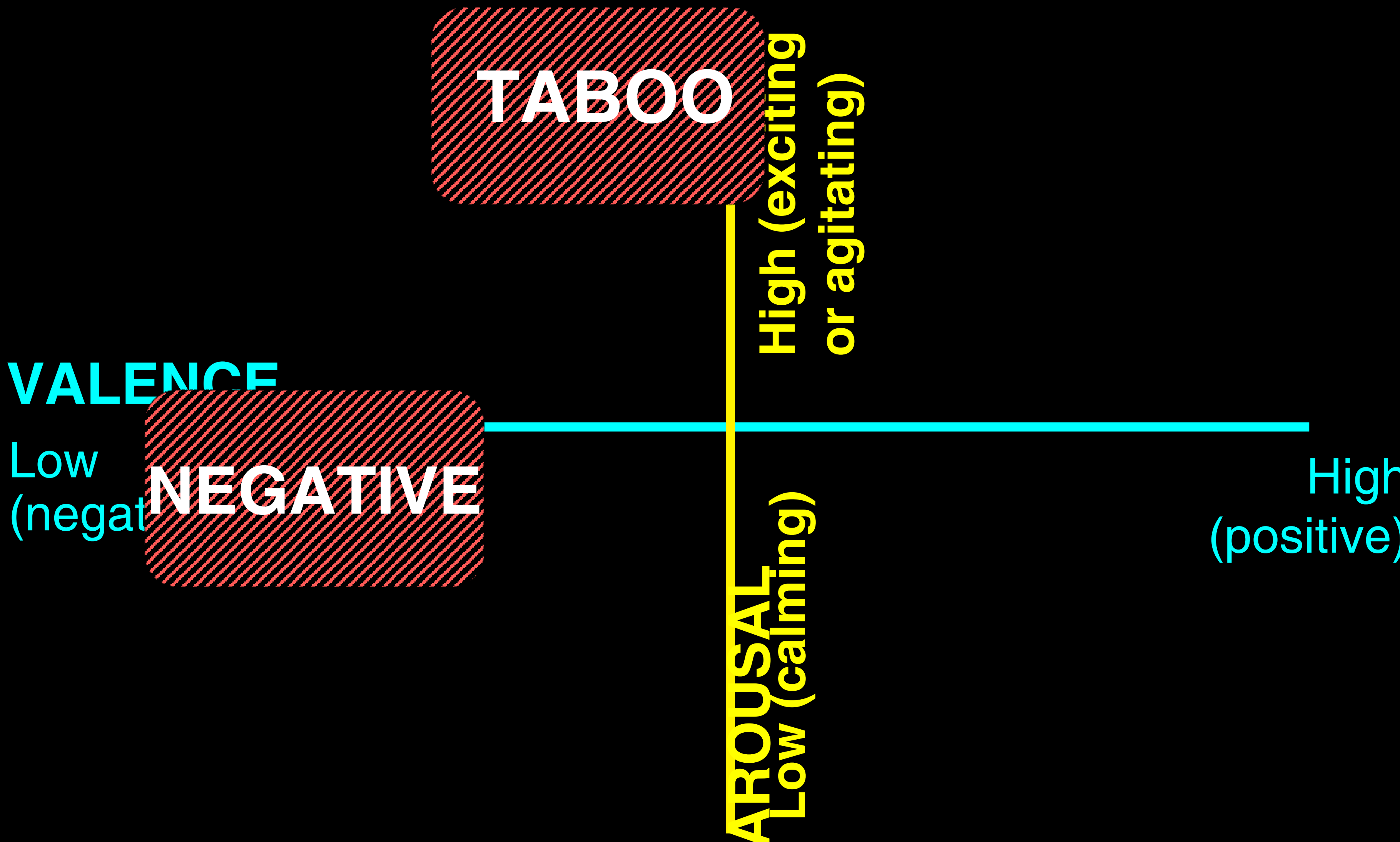
The cortical route for emotional learning involves input from the senses - for example, a visual stimulus - that travels to the visual thalamus, to the visual cortex, to the amygdala. The subcortical route bypasses the visual cortex, with the signal travelling to the visual thalamus and then straight to the amygdala.

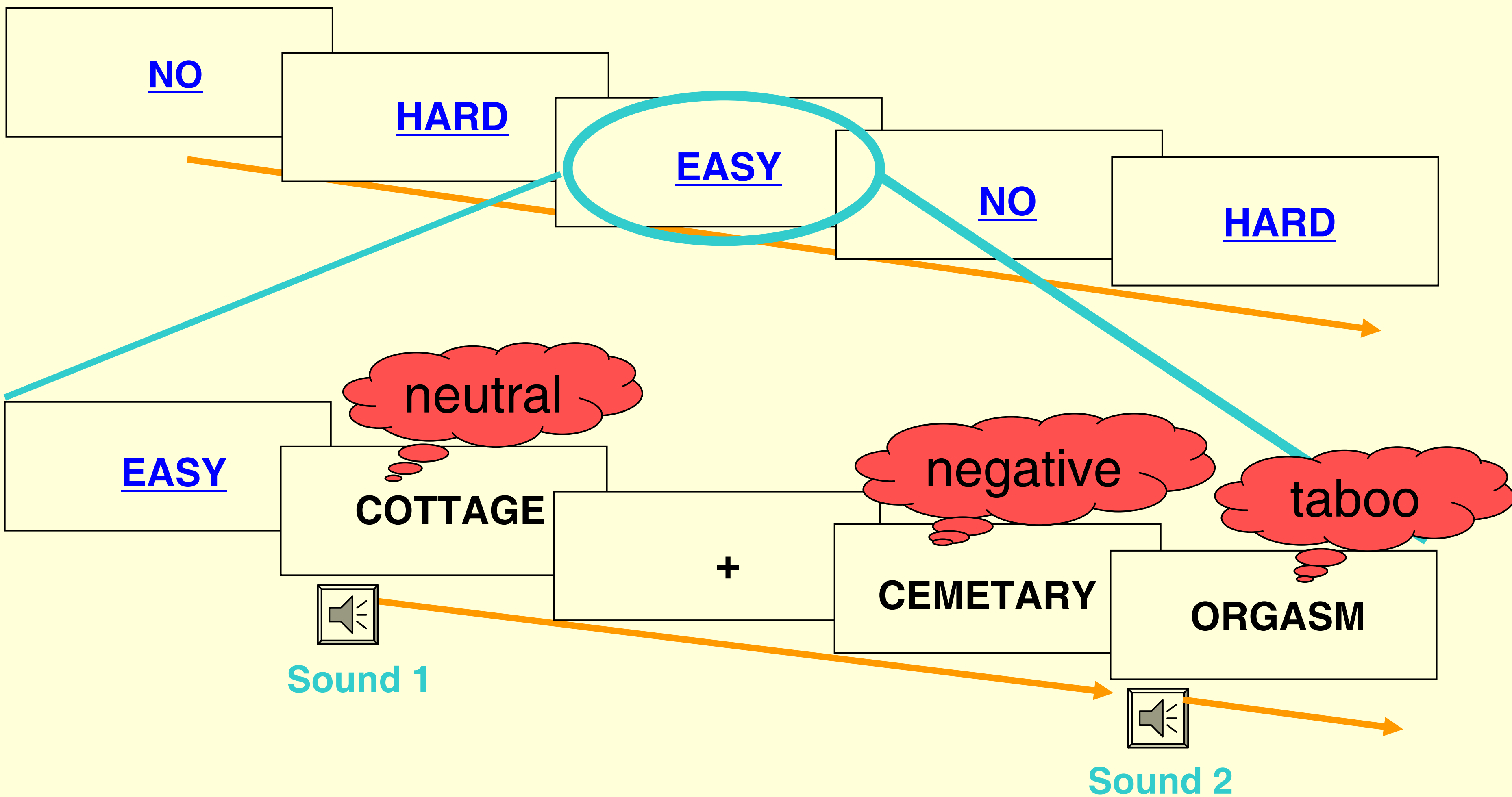
LeDoux, 1994

are there separate *cognitive* mechanisms for valence and arousal?

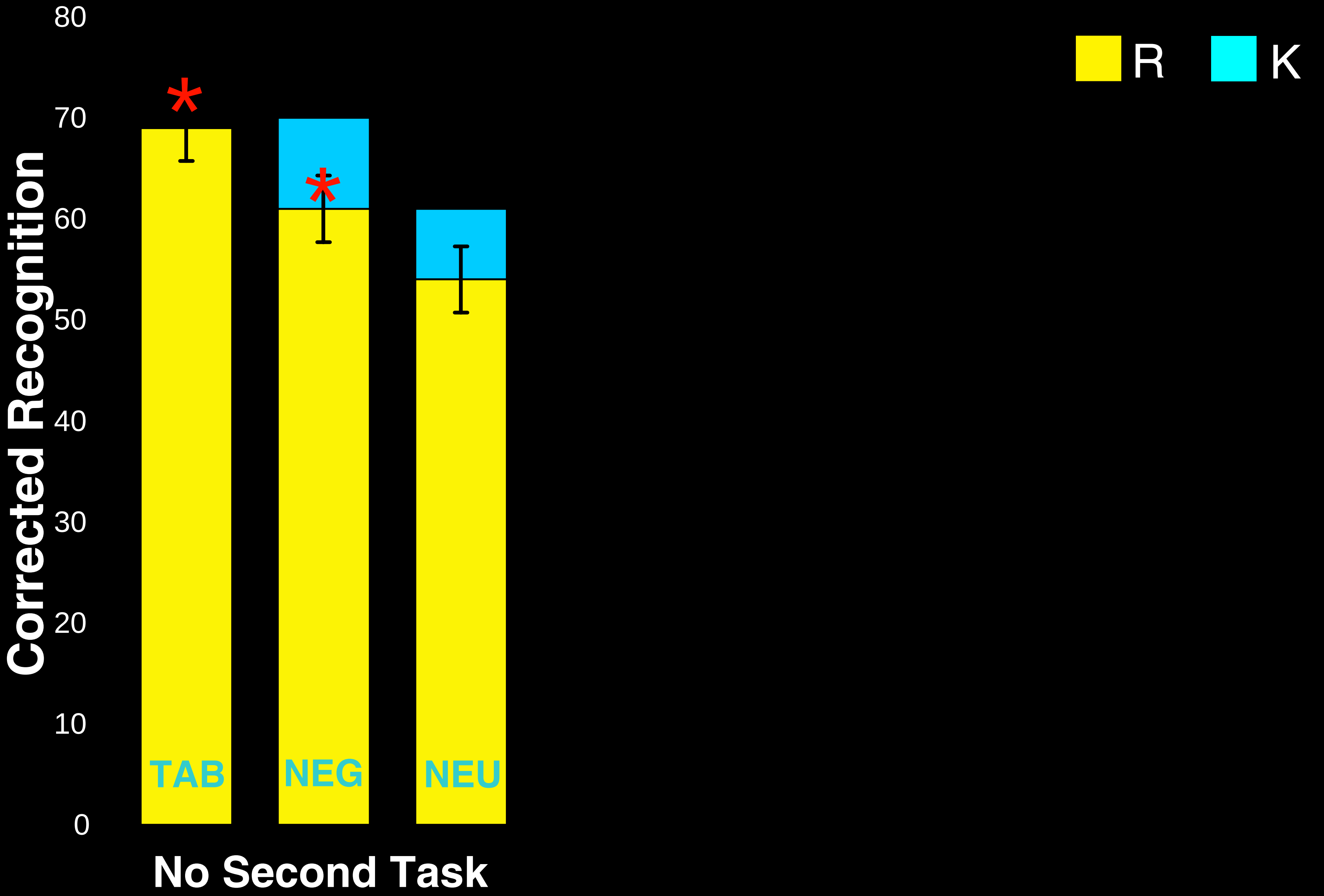


Russell, 1980; Lang et al., 1993

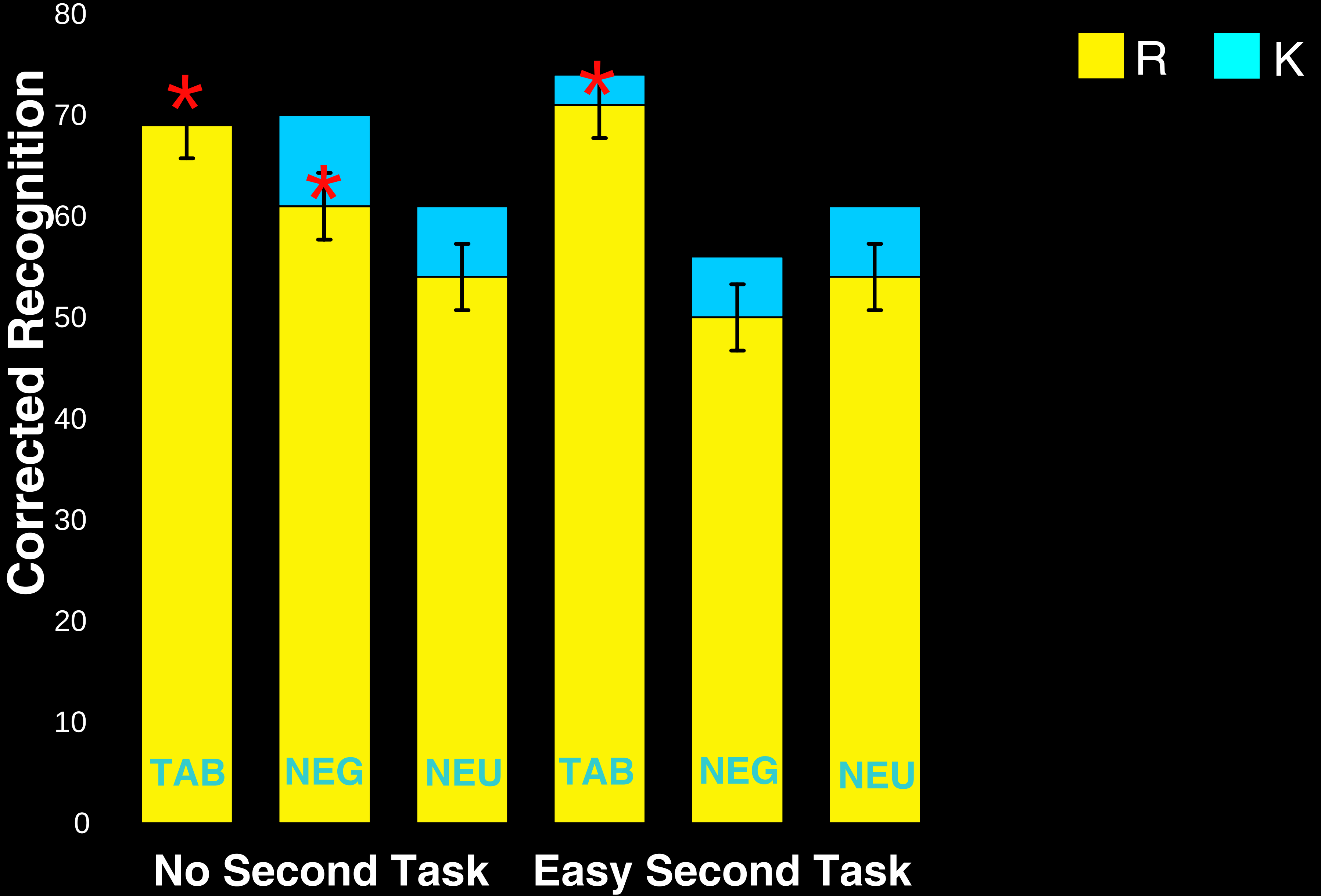
what is the role of attention at encoding?



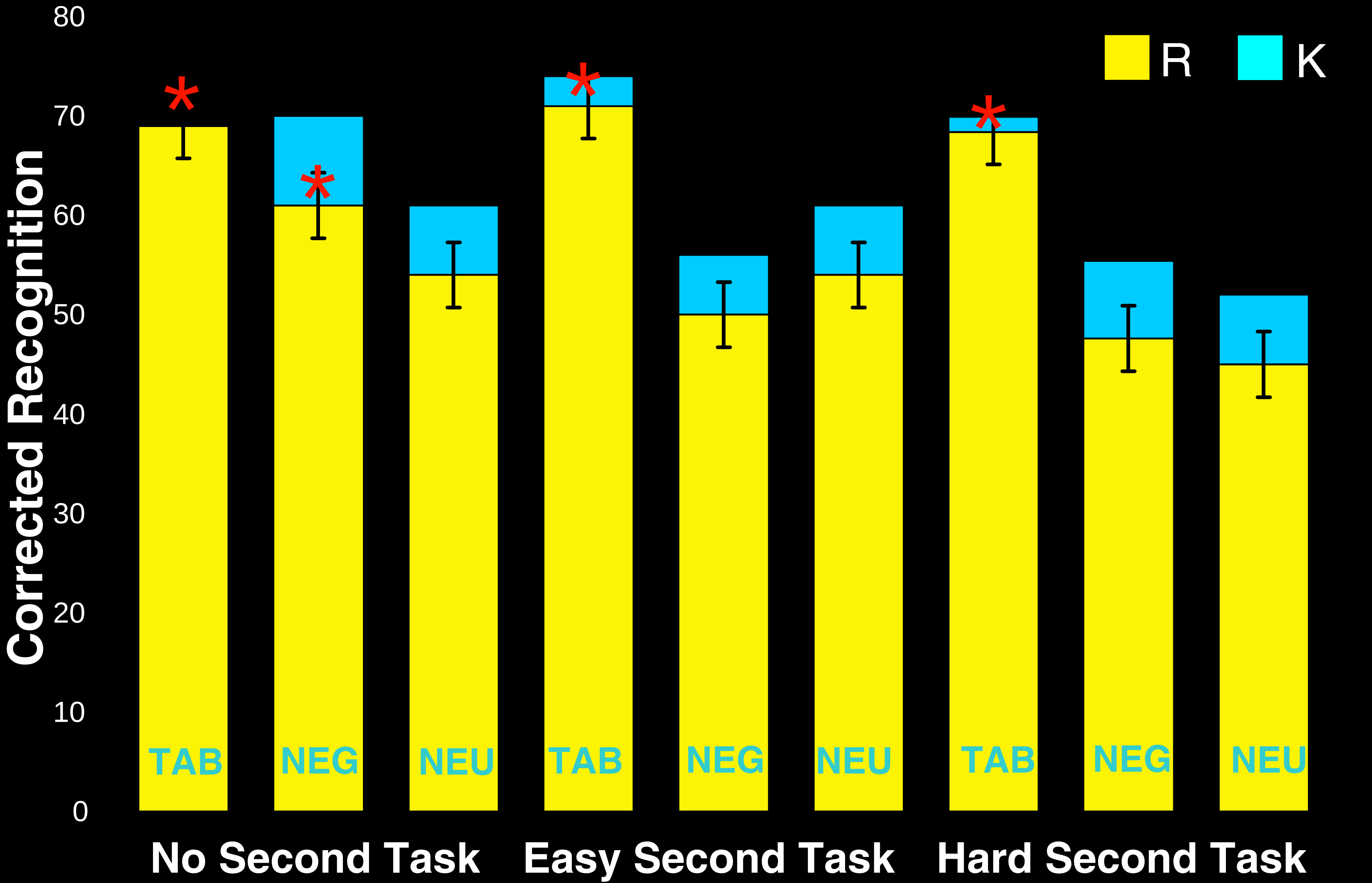
no secondary task: “remember”
taboo > negative > neutral



easy secondary task: “remember”
taboo > valence = neutral



hard secondary task: “Remember”
taboo > valence = neutral



what *cognitive* processes underlie the recollective memory enhancement for emotional information?

VALENCE WORDS

AROUSING WORDS

CONTROLLED (self-initiated)

- intentional, conscious
- attention-demanding

OR

AUTOMATIC

- incidental, not conscious
- not attention-demanding

what *neural* structures support the processing of valence and arousing words to enhance recollection?

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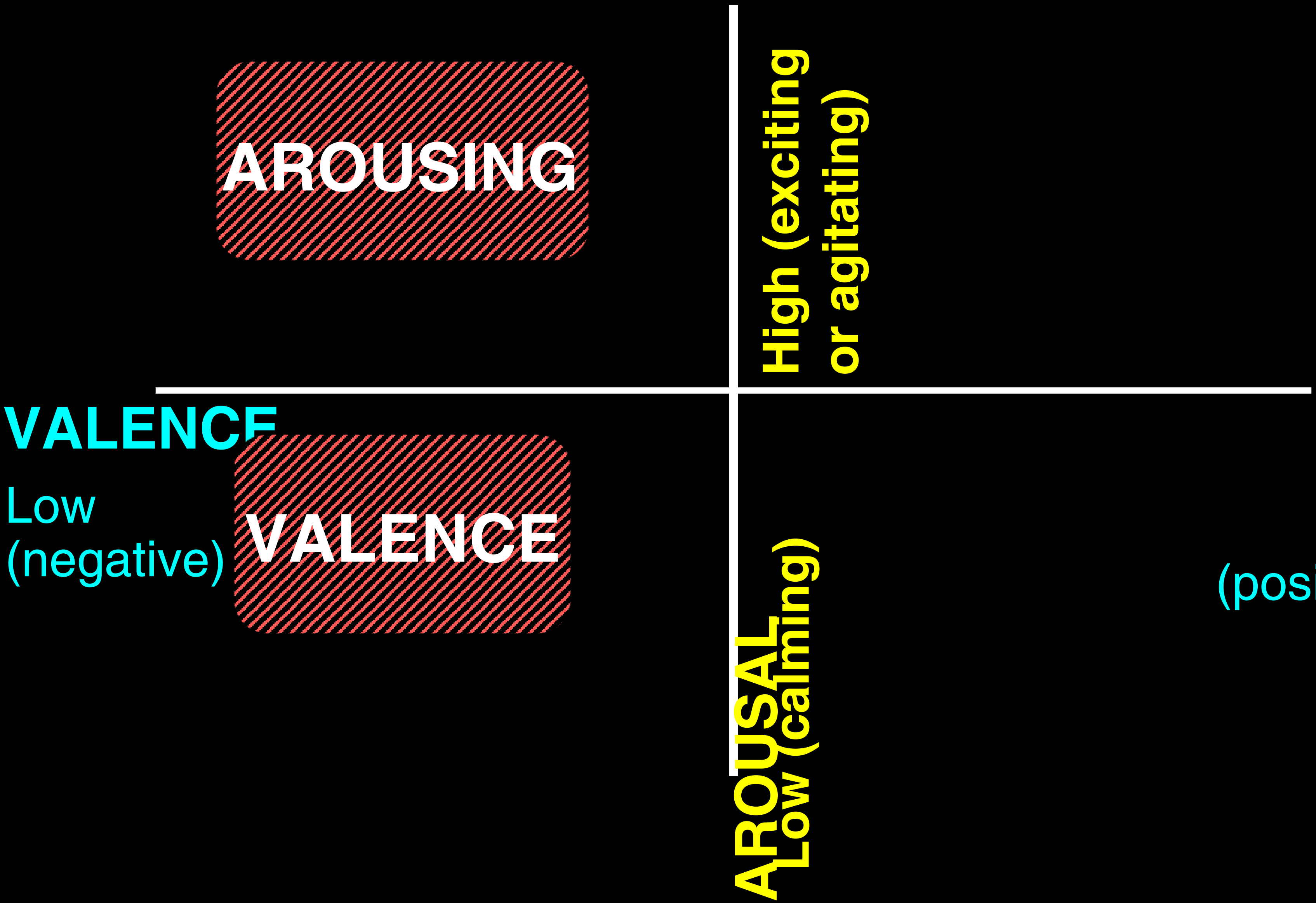
Illustration of a brain with the prefrontal cortex, amygdala, and hippocampus each highlighted.

prefrontal cortex

amygdala

hippocampus

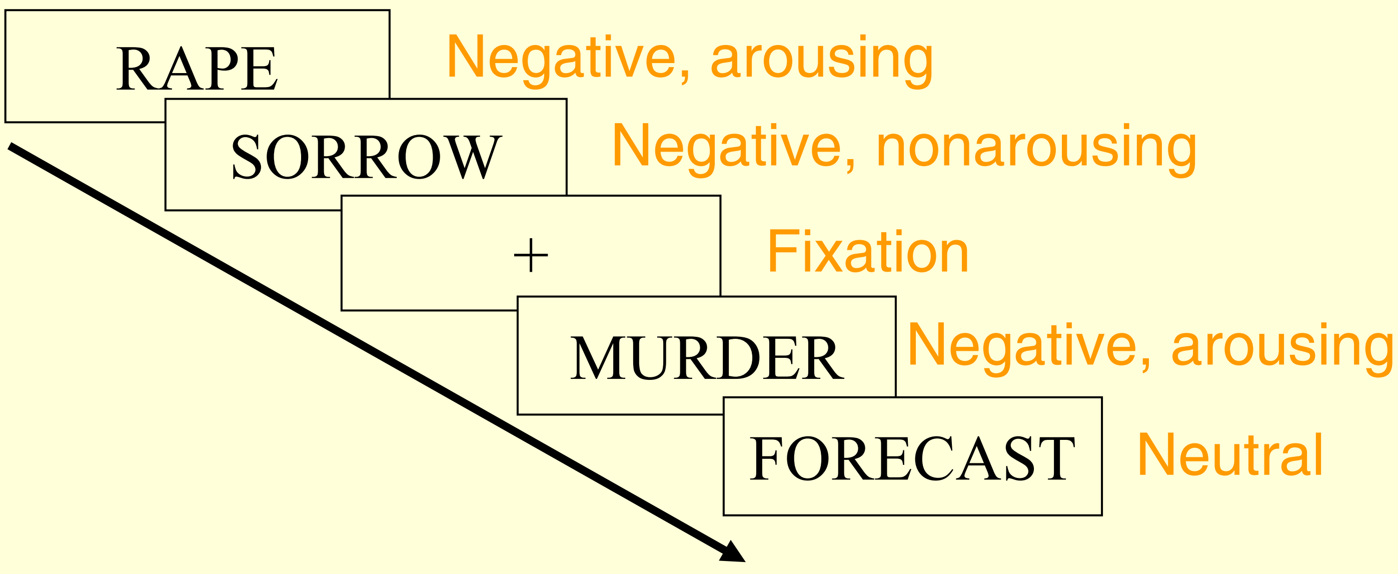
are there separate *brain* mechanisms for valence and arousal?



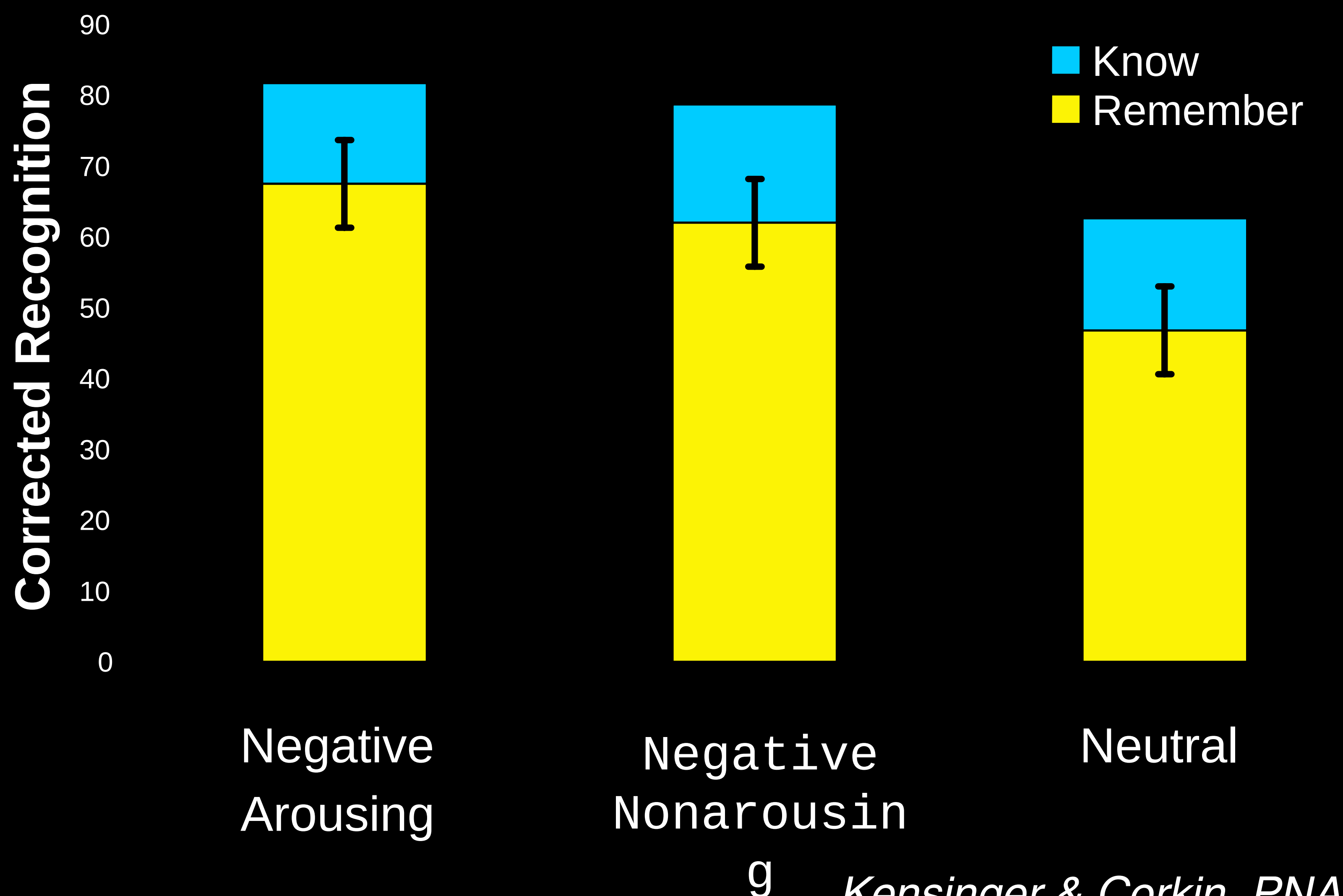
Russell, 1980; Lang et al., 1993

what brain regions support memory enhancement?

14 men , 14 women
3T head-only Allegra scanner
data analyzed using SPM99



memory performance during scanning

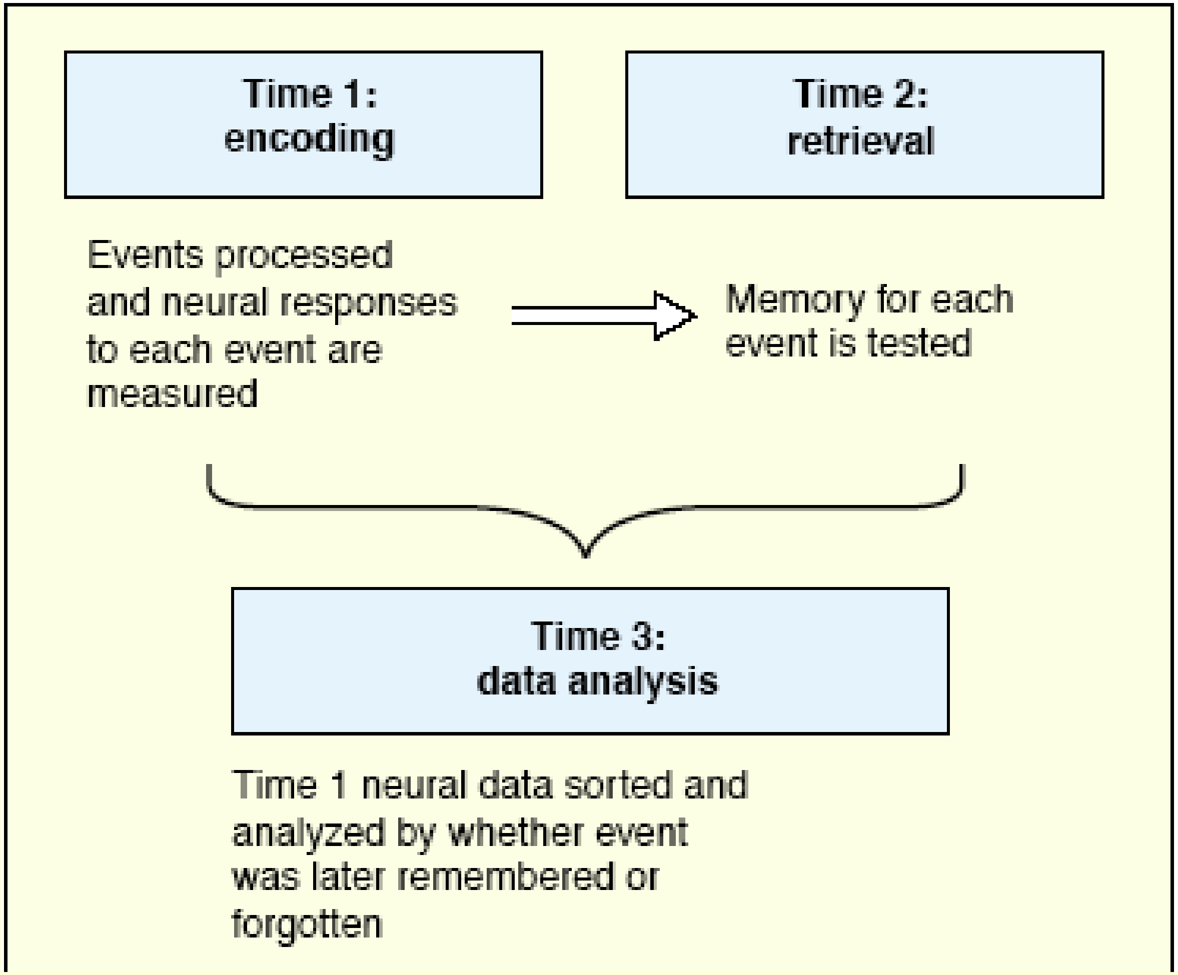


Kensinger & Corkin, PNAS, 2004

are there two brain networks for emotional memory?

- one for ***valence*** (how positive or negative the information is) and
- one for ***arousal*** (how exciting or calming the information is)

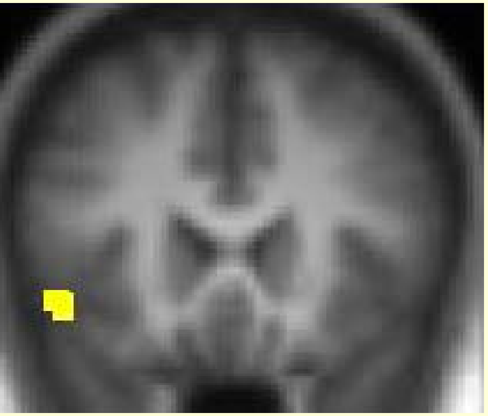
subsequent memory paradigm



Question:
What was the pattern of brain activity when people encoded words they later remembered vs. when they encoded words they later forgot?

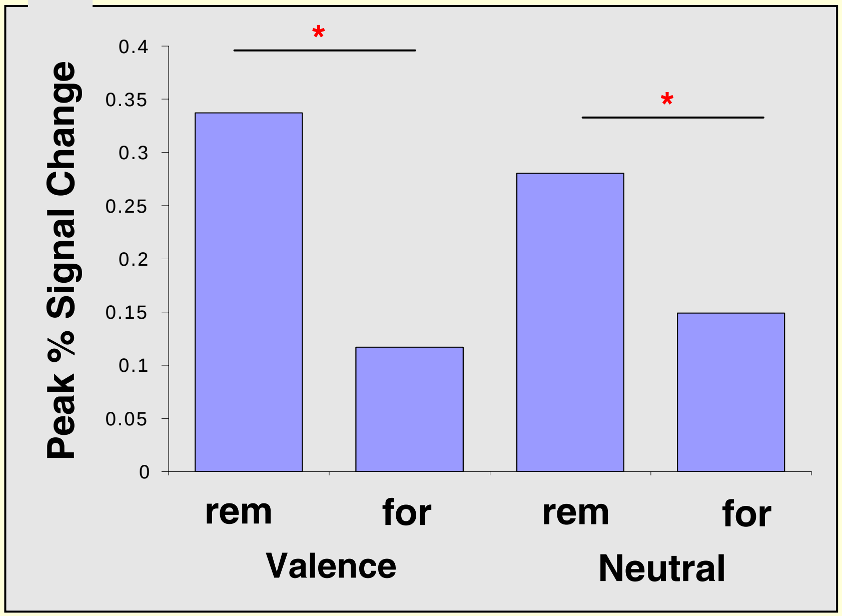
Wagner & Davachi, 2001

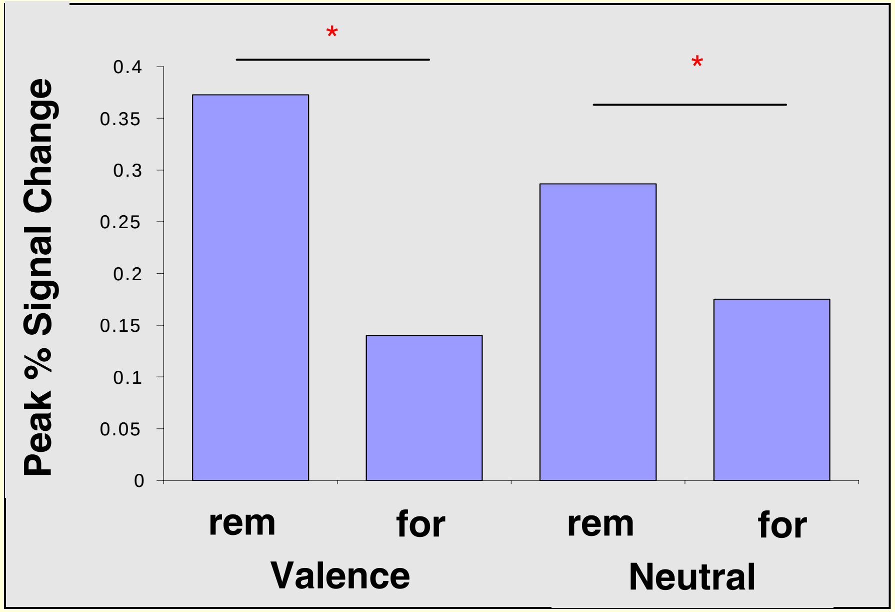
subsequent memory effect for valence (negative) and neutral words: activation in 2 areas predicted successful encoding



L inferior PFC (BA 47)

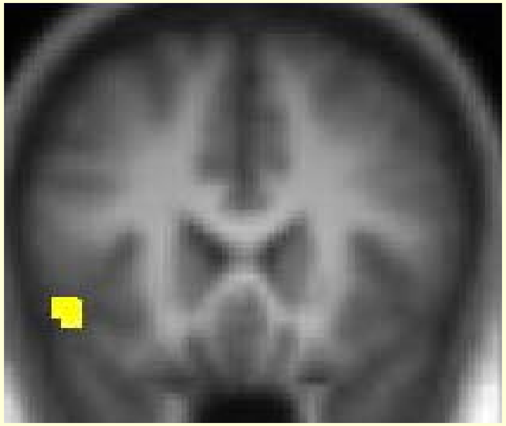
L anterior hippocampus

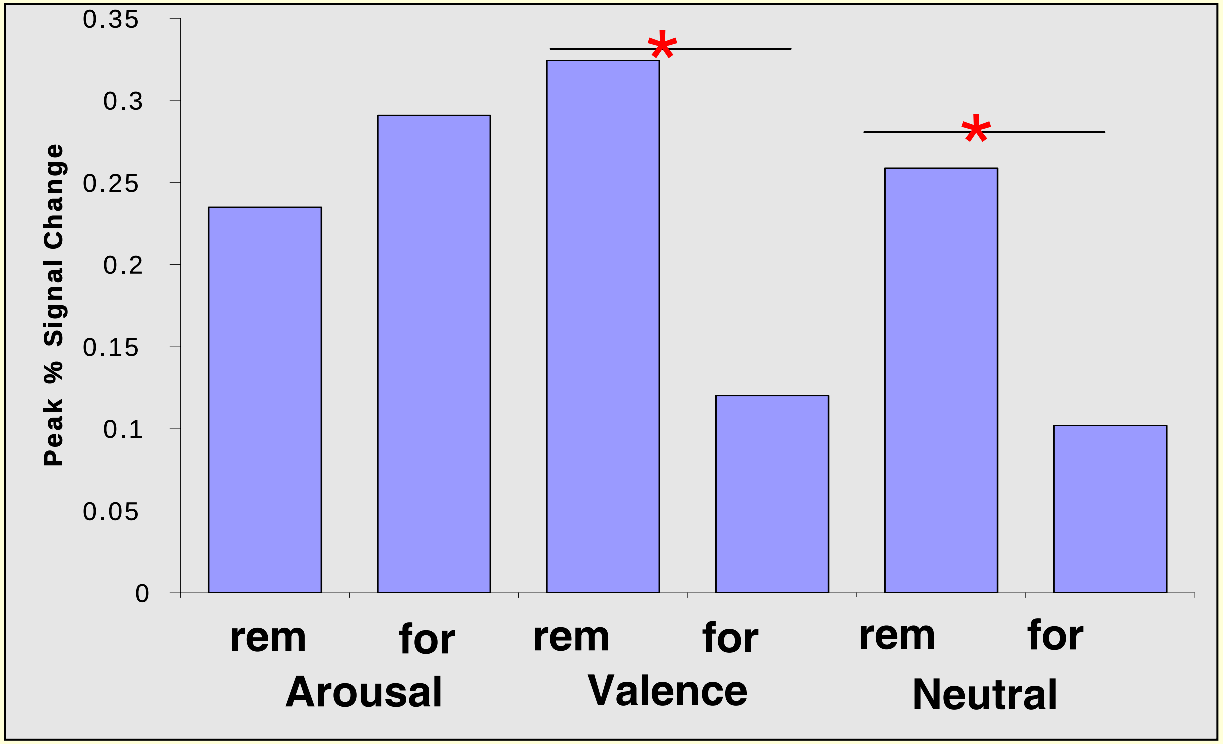




no subsequent memory effect in L inferior PFC for arousing words

L inferior PFC
(BA 47)

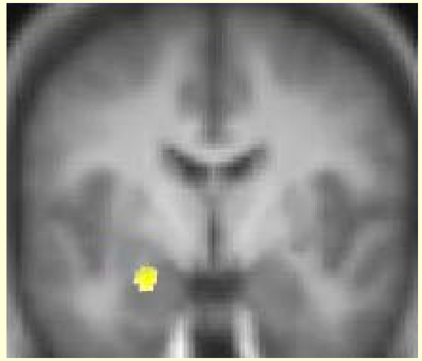


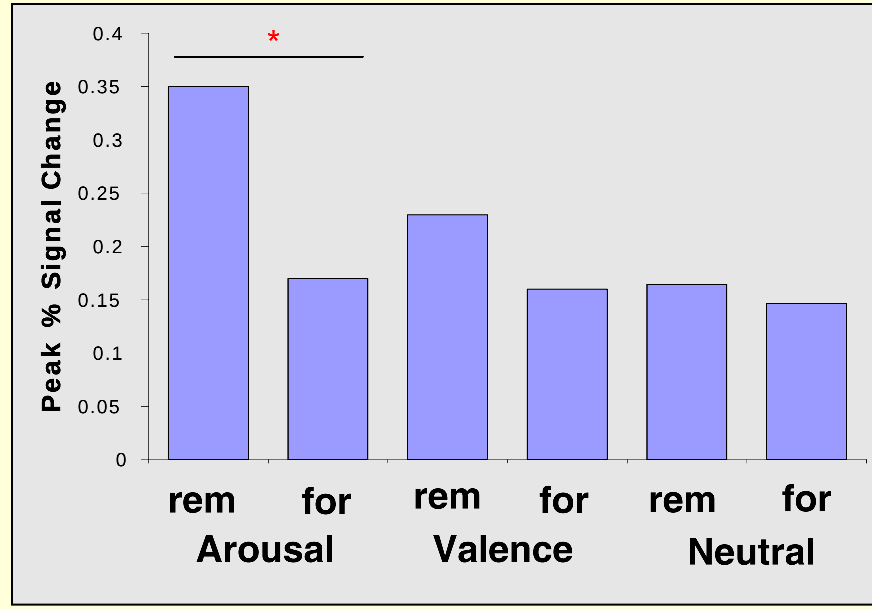


❖subsequent memory effect for arousing (taboo) words

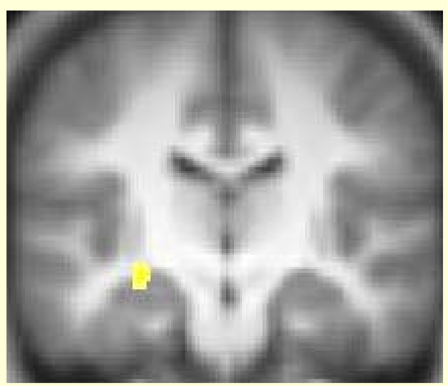
activation in 2 areas predicted successful encoding

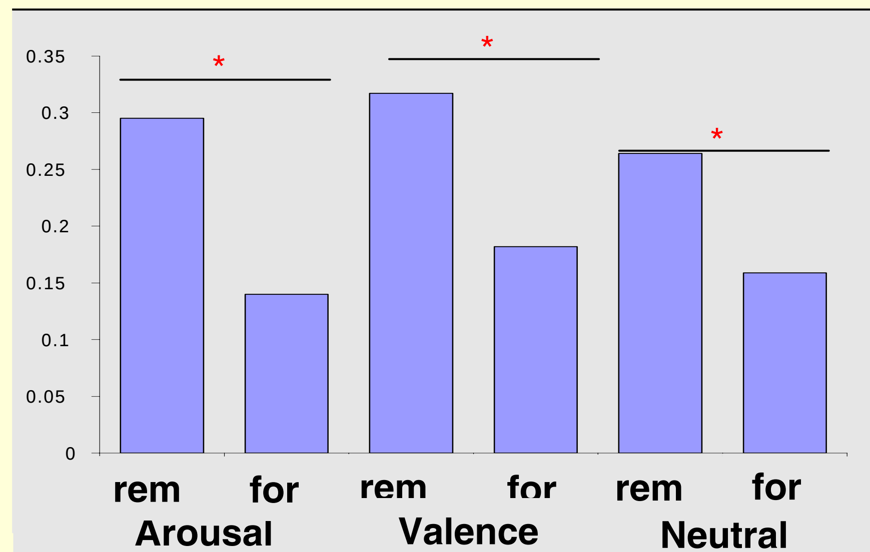
L amygdala





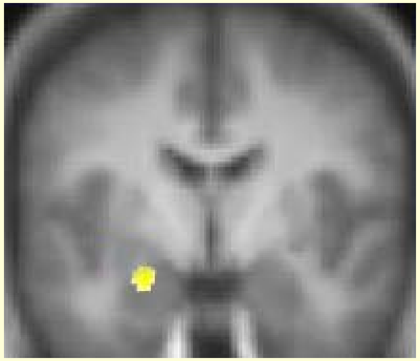
L anterior hippocampus



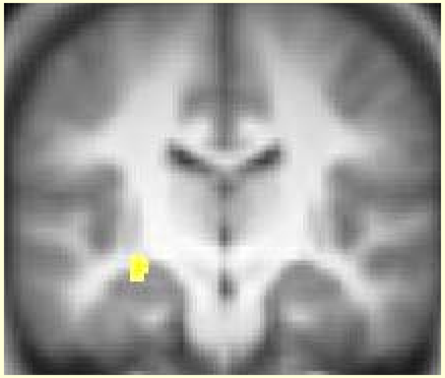


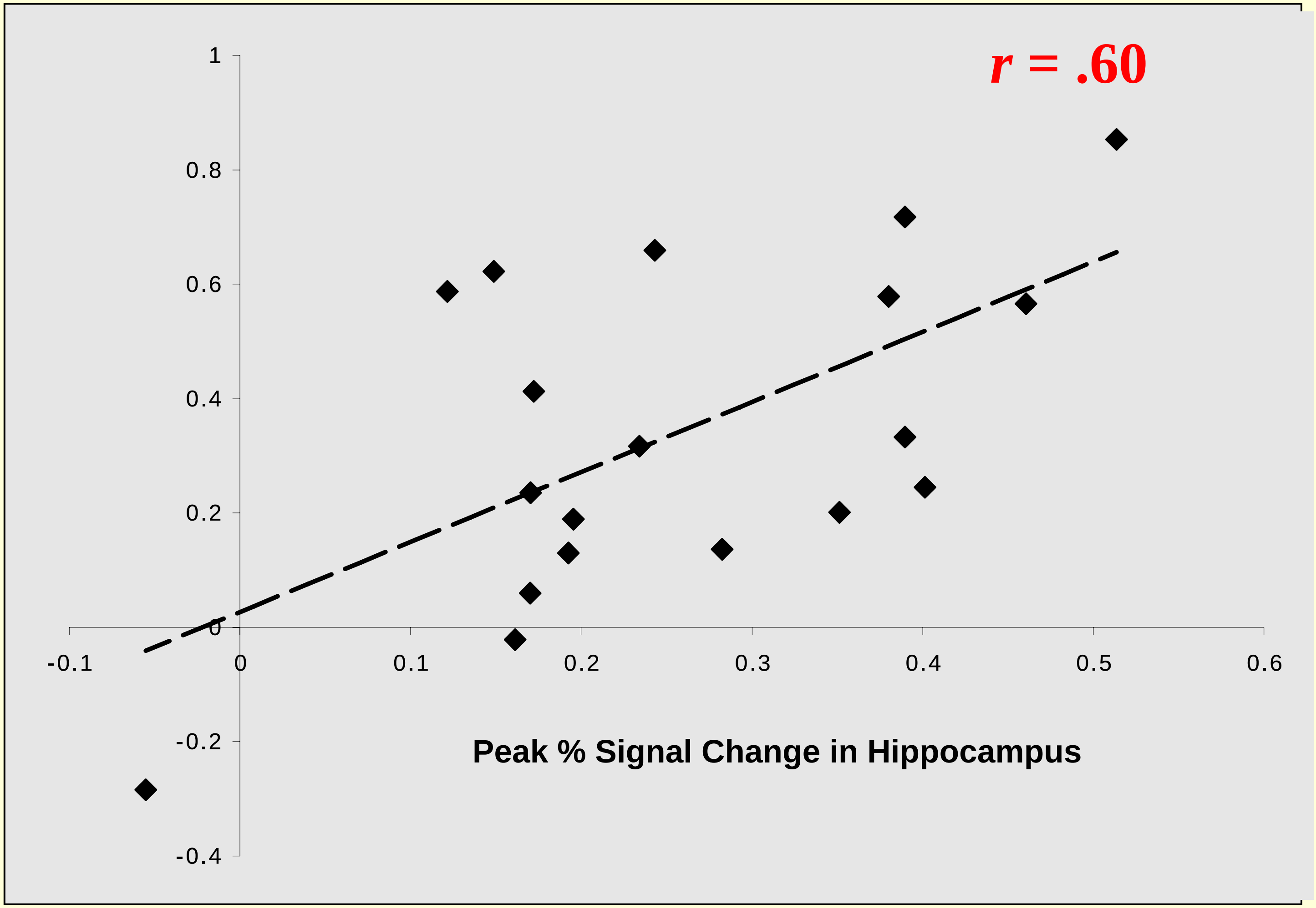
amount of activation in these regions was correlated significantly, suggesting that the 2 areas act cooperatively

L amygdala

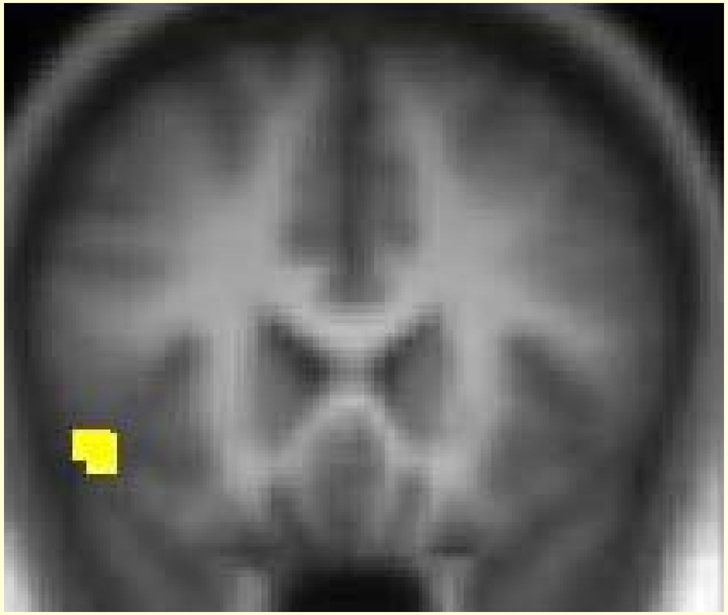


L anterior hippocampus

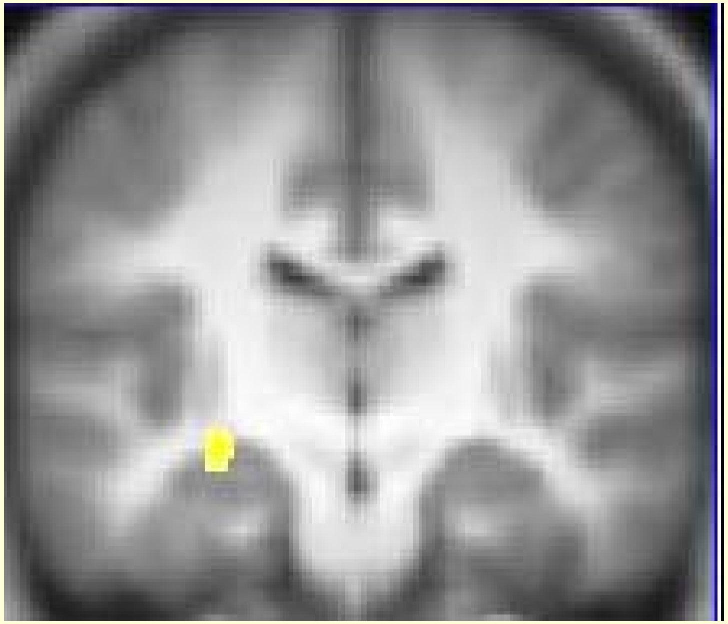




a left prefrontal-hippocampal network supports the recollective enhancement for valence (negative) words as well as for neutral words



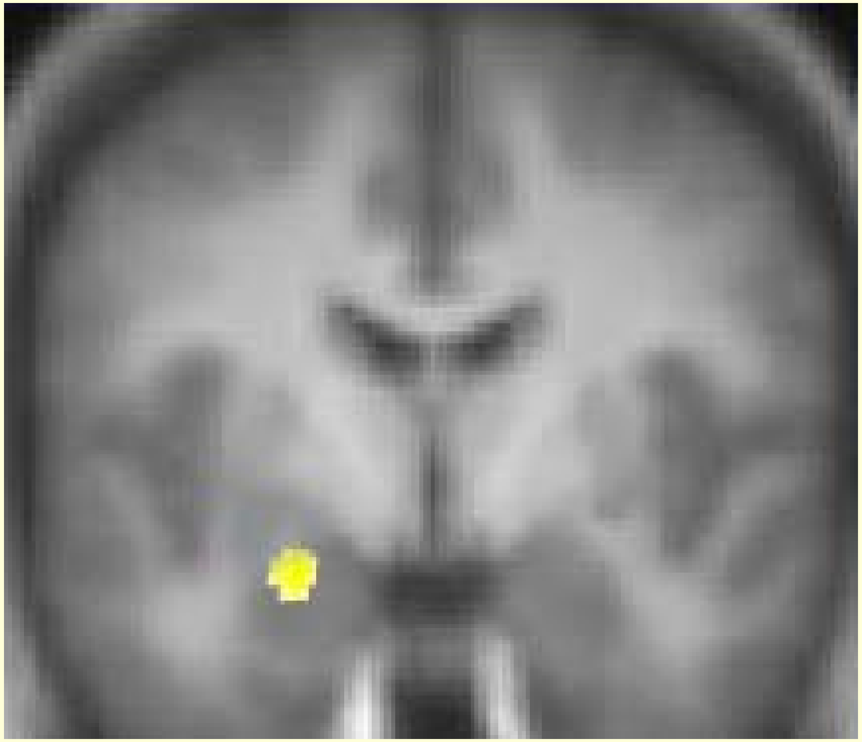
left prefrontal cortex

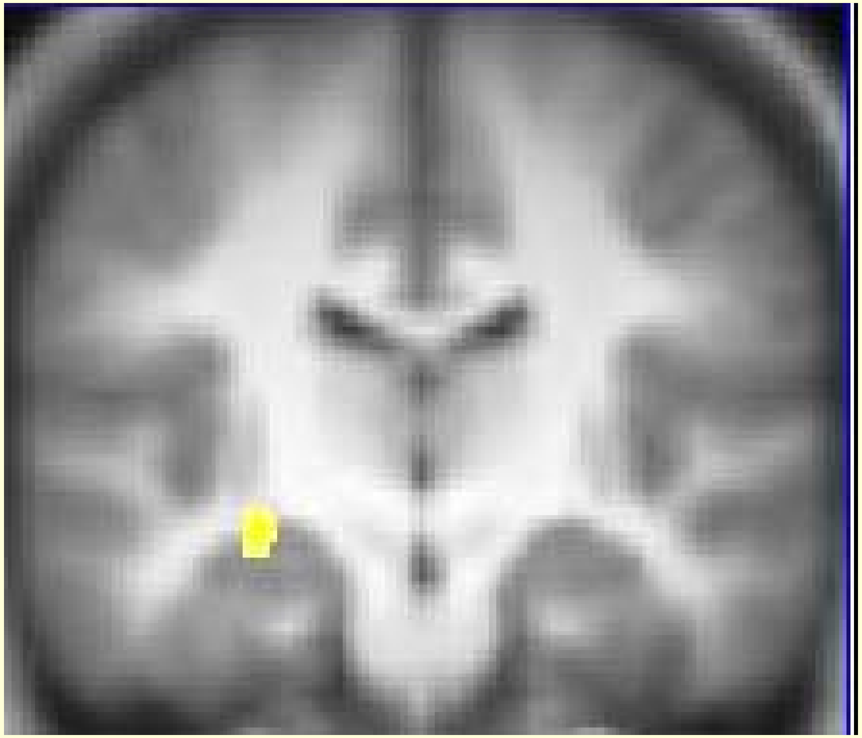


left hippocampus

these areas support controlled processing of information, which results in successful encoding

an amygdalar-hippocampal network supports the recollective enhancement for arousing (taboo) words





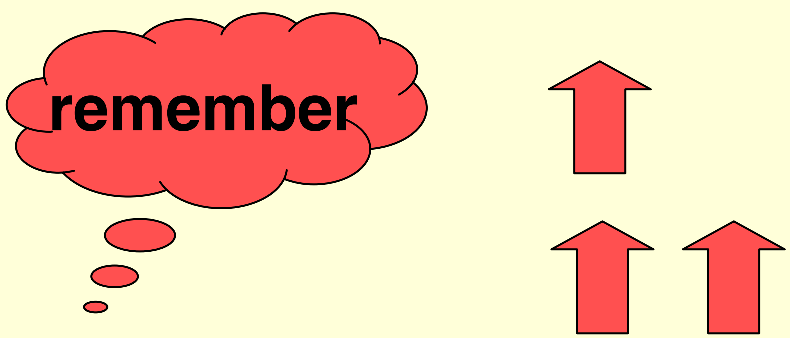
automatic orienting toward emotional stimuli

may benefit memory

conclusions

- items with valence or with arousal are more vividly remembered than neutral items
- this effect is greater for arousing words than for valence words

Word Type	Emotional Memory Enhancement Effect
Neutral	
Valence	
Arousal	



different *cognitive* processes support the enhancement effects

- ***valence*** (negative) words are enhanced by additional, elaborative, encoding processes
- ***arousing*** (taboo) words are enhanced automatically

Word Type	Emotional Memory Enhancement Effect
Neutral	
Valence	⇑ controlled
Arousal	⇑ automatic

different *neural* processes support the enhancement effects

Images removed due to copyright restrictions.

Images of human brains with the relevant areas highlighted.

Word Type	Emotional Memory Enhancement Effect
Neutral	L inferior PFC, L hippocampus (supports controlled processing)
Valence	
Arousal	L amygdala, L hippocampus (supports automatic processing)

time for questions & 2 student presentations

Image removed due to copyright restrictions.
Photo of a very stressed-looking woman.