On Laughter and Forgetting and Reconversing: A neurologically-inspired model of conversational context

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Abstract

We argue that phenomena from both dementive and neurotypical individuals motivate the need for a synthesis between existing formal semantic theories of dialogue context and theories of memory and emotion. We sketch here such a synthesis: we embed certain very transient aspects of dialogical semantic states as components of a Multicomponent Working Memory (Baddeley, 2012) style working memory and we also sketch how to embed dialogues globally within Long Term Memory. We exemplify how the emergent framework can account for the conversational phenomena.

1 Introduction

Consider the exchange in (1) between nurses and inhabitants of a care home suffering from dementia. The nurses are prompting the patients to complete well known Swedish proverbs. Among this cohort, studied by Lindholm (2008) laughter is commonly used to mark memory failure.

(1) a. NURSE: strain at a gnat and, (0.5 sec) PATIENT: (ah) (0.8 sec) *nothing else* [heh heh heh] NURSE: strain at a gnat and swallow a camel. (Lindholm, 2008, ex. (2))

b. NURSE1: no smoke, (1.9) PATIENT: (.h) without (1.7) heh heh heh NURSE2: fire ((whispers)) (Lindholm, 2008, ex. (3))

Note that cases such as (1) are not limited to people with dementia, as in the constructed (2)—here after a failure by the speaker to recollect the name or title of a particular individual, they reformulate and laugh about it:

(2) A: The ... whoever it is (laughs) decided against reopening the schools.

In order to develop an account of examples such as these, we need to synthesize at least three ingredients: a theory of dialogue meaning and coherence (to explain the coherence requirement of the nurse's and patient's responses, and the content of self-repairs and laughs), a theory of memory incorporating long-term and short-term/working memory (LTM, WM) distinctions, and a theory of emotion to explain certain of the effects brought about by laughter; indeed recent work has demonstrated the need for synthesizing emotion and dialogue given the complex dialogical meaning of signals such as laughter and frowning (Ginzburg et al., 2020). As we discuss in section 2, (Neuro)Psychological Memory theories help explain memory *failure* in terms of (i) trace deterioration caused, e.g., by lack of consolidation (Wixted, 2004), by time–dependent contextual drift (Sadeh and Pertzov, 2020), or by disease, or (ii) capacity limits—the episodic buffer, assumed to serve as a link to perception and to LTM and to hold multidimensional representations, is assumed to hold up to four chunks. However, since no semantics is assigned to traces and such theories lack notions of relevance, they cannot be used to explicate partial recollection and how patients react to their failure, as in the laughter in (1) and (2), or in the question posed in (3). For the latter, such theories can be used to explain the confusion evinced by the patient in terms of working memory capacity, as we explain below, but not the emergence of the clarification question:

(3) (Context: B (a dementia patient) is watching a concert on television featuring wind instruments while eating dessert consisting of cooked apples): How will the apples get through the pipes? (Citation-suppressed, 2019)

Dialogical theories of context (e.g., Ginzburg, 2012; Lascarides and Asher, 2009) have as their inspiration logical derivation architectures and they offer intricate notions of relevance and inference. However, their Achilles heel is the absence of forgetting and of explicit interface with LTM.[1] Forgetting has typically been viewed as a “performance” issue to be finessed at a future date. But as illustrated in (4a), it can play an important role in dialogues with dementive patients, and even with neurotypical participants.

(4) a. A: When will you come? B: Not for a few weeks. A: Yes. B: So good night. A: So will you come tomorrow for lunch? B: I’m not in town. A: Yes. B: So good night. (Citation-suppressed, 2019)

b. A: When will you come? B: Not for a few weeks. A: (absent mindedly) Yes. (10 minutes later) A: So, when are you coming? B: I told you! A: Sorry, I was multi-tasking.

A converse issue, showing the need for an explicit interface with LTM, is the phenomenon of resumed conversations, as in the constructed example (5):

(5) A: How can we solve the equation? B: I’ll have to think about it, but now I have to run.
(3 days later) A: So? B: Right, yes,um I’d say just integrate three times and . . .

Indeed, continued resumption is important as far as inner dialogue goes (on which see Kracht, 2010), which is particularly relevant for therapeutic genres, where apparently resolved issues can rearise indefinitely (as has been reported, for instance, for depression (Curry, 2014) and schizophrenia (Kennedy and Xyrichis, 2017)).

The rest of the paper is structured as follows: in section 2, we review literature on memory, emotion, and dialogue. We effect a synthesis in section 3— implement basic linguistic and non-verbal interactions including signs in a memory–oriented and felt way. We return to the above examples in section 4.

[1]Absence of forgetting is not to be conflated with lack of structure. Such theories have means to limit accessibility to antecedents, including structural (e.g., the right frontier constraint), stacking/partial ordering of contextual repositories such as QUD. But once a proposition becomes part of the common ground, however modelled, then it remains as such, unless eliminated by correction.

2 Background

2.1 Memory

Recent (neuro)psychological work Recent work on memory has offered evidence for various distinct kinds of long-term memory (LTM) systems and the brain areas they activate—much of it based on disassociation phenomena (Bastin et al., 2019). (6a,b) exemplify two distinct types of memory failure: partial recollection (details of an event) and loss of familiarity (with an entity):

(6) a. Inv: Who did you go with? Man: Went with you (wife). Wife: yeh me and who else? Man: I don’t know. Wife: Trevor (son) Man: Aye Trevor. (From Shakespeare, 2013 extract 2)

b. Son: Who am I? Mother: I don’t know. (Shakespeare, 2013 extract 23)

The LTM systems include: the relational episodic (hippocampus), entity (perirhinal and parahippocampal cortices), and the procedural (striatum) subsystems. With respect to working memory (WM) Baddeley (2012) summarizes a model, Multicomponent Working Memory (M-WM), that has been highly influential in the last 40 years: on this view, M-WM has four components and informational flow, as summarized in Fig. 1 (slightly simplified from Baddeley, 2012, Fig. 5). Initially, as described in (Baddeley, 1997), the framework had three components, the C(entral) E(xecutive), the phonological loop (phon-loop), and the visuo-spatial sketchpad (VSSP). The basic idea here is to split attentional control from temporary storage—the phonological loop and the visuo-spatial sketchpad correspond to separate verbal and visuo-spatial short-term systems, which are limited in capacity. The phonological loop has been argued to be necessary for new long-term phonological learning and to play a significant role in the initial stages of vocabulary acquisition. The CE serves four main functions (Baddeley, 2012, 14): 1. focus attention, 2. divide attention, 3. switching between tasks, and 4. interface with the LTM. 25 years after the initial 3 component model, an additional component was postulated, namely the *episodic buffer*. This is a buffer that can maintain information from several modalities that has been bound together by the central executive. (Baddeley, 2012, 17).

There are still a variety of open issues in this area:

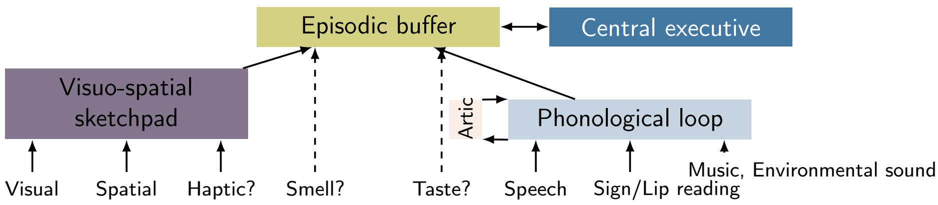

Figure 1: M-WM (Baddeley, 2012)

- Baddeley's phon-loop is a (speech-based) short-term storage, while the episodic buffer is a chunk based mechanism. Cowan (e.g. Cowan, 2008) claims that there is not enough empirical evidence to differentiate two processing limiting systems; he rather argues for a single 'attentional system used both for processing and for storage' (*op. cit.*, p. 13) that operates on activated areas of the LTM. However, as Baddeley (2012, 20) remarks, Cowan's concerns pertain mainly to the CE and the episodic buffer (in M-MW's terms) so that there is a at least a terminological 'translation' between both accounts.

- Both Baddeley's episodic buffer and Cowan's focus of attention are chunk limited buffer stores (Cowan's focus of attention also acts as a temporal storage – see the previous item), and both models by and large agree on a capacity limit of four chunks (Baddeley, 2012, 15). In fact, Cowan (2001) argues in great detail for a limit of four chunks of short-term memory processes (though there still is some discussion, as the comments to Cowan's article show). However, a chunk may itself be a compound structure, for instance, in case of multimodal representations (i.e., bindings of various VSSP and possibly also phon-loop stimuli), so that there is some flexibility concerning the complexity of the chunks themselves. In any case, a short-term memory limit of four chunks seems to be a first capacity constraint for dynamic semantic theories, as desired in Sec. 1.

- Alternative proposals suggest that, in fact, the correct generalisation is that one can maintain only *one* temporally extended *event* or *epoch* in focal attention (McElree and Dosher, 2001).

2.2 Emotion

There are a variety of theories of emotion. Although important early work on facial gestures came from researchers espousing theories postulating a small number of *basic emotions* see e.g., Ekman et al. (1987), there has been little evidence to support the existence of physiological characteristics that instances of a single emotion share but that other emotions do not (Scherer and Ellgring, 2007; Barrett, 2017). A variety of approaches have emerged that avoid such an assumption. We mention here two influential approaches, *emotion constructivism* and approaches based on *appraisal*; both provide useful means for classifying laughables, smileables, sighables (the events triggering such signals) etc and the emotional episodes they give rise to.[2] Emotional episodes are viewed as arising from a categorisation process of the triggering event in terms of previous event 'exemplars' on the basis of a resemblance in terms of certain dimensions (Russell, 2003; Barrett, 2017). In the account of Russell (2003) these include *core affect* (a two dimensional matrix of (un)pleasantness and arousal), *affective quality*, and the object causally involved in the event. With respect to neural implementation, one might mention latency results from a recent extensive review of intracranial recordings of the human amygdala, one of the key junctures in affective processing (Murray et al., 2014; see Fig. 2 for an illustration). This suggests that the amygdala neuronal activity occurs in three latency windows: an early window subsumes effects respective to exogenous stimulus-driven affective processing of faces and emotion; an intermediate window consists of effects related to explicit attention to novel task-relevant stimuli, irrespective of sensory modality; whereas, the late window subsumes effects from tasks soliciting working memory, semantic processing, attentional focus and memorization dur-

[2] For discussion of the similarities and differences between these approaches, see Brosch (2013); Barrett (2017); Sander et al. (2018).

ing affective processing.[3]

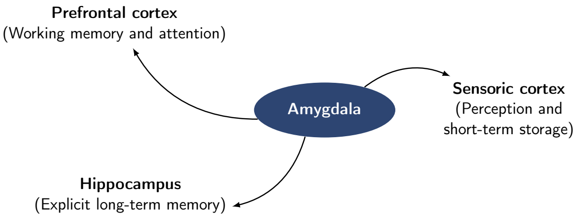

Figure 2: (Reproduced from LeDoux, 2001, 308) Regions of the amygdala project into various cortical regions. This includes projection into all stadiums of cortical sensoric processing, into the prefrontal cortex an to the hippocampus and its neighbouring cortical areas. Based on these projections, the amygdala influences current perception, imagination, attention, short-term memory, working memory, long-term memory, and various higher-order thought processes resting on the former.

2.3 Dialogue

We use KoS (Ginzburg, 2012) for modelling dialogue for two reasons: (1) as we explain below, it is already partially structured in memory terms (2) it is underpinned logically by Type Theory with Records (TTR) (Cooper, 2020), whose structured nature enables writing both memory trace construction rules and de-activation principles. In TTR propositions are identified with records of the type $\begin{bmatrix}\text{sit:Rec}\\ \text{sit-type:RecType}\end{bmatrix}$, involving a situation *sit* and a situation type *sit-type* and true iff sit:sit-type.

KoS as a theory of dialogue offers a theory of how utterances and other events change an individual's perspective of the public context, by developing an account of a highly structured class of states—*dialogue gameboards*. Dialogue gameboards track various aspects of the emerging context, including turn ownership, shared assumptions (FACTS), questions under discussion (QUD), the visual field, moves that are in the process of being or have been grounded (Pending, Moves) and MOOD—a weighted sum of appraisals. Here MOOD represents the publicly accessible emotional aspect of an agent that arises by publicly visible actions (such as non-verbal social signals), which can but need not diverge from the private emotional state.

$$
\mathit{DGBType} := \begin{bmatrix}
\text{spkr} & : \mathit{Ind} \\
\text{addr} & : \mathit{Ind} \\
\text{utt-time} & : \mathit{Time} \\
\text{c-utt} & : \text{addressing(spkr,addr,utt-time)} \\
\text{facts} & : \mathit{Set}(\mathit{Prop}) \\
\text{vis-sit} & = \begin{bmatrix}\text{fova} : \mathit{Ind} \vee \mathit{Sit}\end{bmatrix} : \mathit{RecType} \\
\text{pending} & : \mathit{List}(\mathit{LocProp}) \\
\text{moves} & : \mathit{List}(\mathit{IllocProp}) \\
\text{qud} & : \mathit{poset}(\mathit{Question}) \\
\text{Mood} & : \mathit{Appraisal}
\end{bmatrix}
$$

Such cognitive states can represent the results of locutionary, (7a,b), illocutionary updates, as in (7c,d), and emotion-based updates, such as (7e):

(7) a. Utterance integration: an utterance is perceived, updates Pending as a *locutionary proposition* (a record consisting of a representation of the utterance u and a grammatical type T_u calculated to classify it, exemplified in section 3; there is then an attempted instantiation of the contextual parameters of T_u; if successful, the locutionary proposition is updated with the contextual instantiation and an attempt is made to find an appropriate Move update rule; if successful, Moves gets updated; otherwise repair ensues: the utterance remains in Pending and a clarification question is calculated and posed.

b. Clarification question: if A's utterance u is in Pending, QUD can be updated with the question *What did A mean by u*.

c. Ask/Assert QUD-incrementation: given a question q and ASK(A,B,q)/Assert(A,B,p) being the LatestMove, one can update QUD with q/p? as MaxQUD.

d. QSPEC: this rule characterizes the contextual background of reactive queries and assertions—if q is MaxQUD, then subsequent to this either conversational participant may make a move constrained to be q-specific (i.e., either a direct answer or a sub–question of q).

e. Positive affect incrementation of Mood: given the LatestMove being an incongruity proposition by the speaker, the speaker increments the (positive) pleasantness recorded in Mood to an extent determined by the laughter's arousal value.

[3]An anonymous reviewer for SemDial asks whether we think that these windows correspond to the three dimensions that in Russell's account underlie the categorization process, namely core affect(a two dimensional matrix of (un)pleasantness and arousal), affective quality, and the object causally involvedin the event. We think this is an interesting hypothesis, but do not have evidence to support/refute this currently.

KoS provides a theory of meaning for highly context dependent elements such as non-sentential utterances (8a,b) and non-verbal social signals such as laughter (8c), which figure further below.

(8) a. yes $\mapsto$ p (p? is MaxQUD);

b. Dunno ('I don't know') $\mapsto$ ¬Know(spkr,MaxQUD)

c. Right $\mapsto$ Understand(A,u) (u is MaxPending, A current speaker);

(all Ginzburg, 2012)

d. Um $\mapsto$ Makes λxMeanNextUtt(spkr,Pending,x) MaxQUD (Ginzburg et al., 2014)

e. laugh: Given A as speaker, l as laughable event, τ as topos $\mapsto$ Assert(A, Incongruous(l, τ)) (Ginzburg et al., 2020)

3 Synthesizing Memory, Emotion, and Dialogue

3.1 Distributing the DGB between WM and LTM

In synthesizing KoS and M–WM, there are two main issues:

1. how to ensure that while the mechanisms we use for dialogue states are individual memory states, they represent records of *interaction*?

2. how to partition the various components of the DGB across WM and LTM?

With respect to the first issue, we will make a rather obvious move, namely view each conversation as an *episode*, one which gets initialized by the first move—typically a greeting—and concluded by the final move—often a (counter)-parting. Our conversations, then, constitute a particular class of episode, which DGBs provide structure for, so are subsumed within episodic memory:

(9) a. Conversation initiation: add the conversation as the next episode in LTM, with its initial state characterized by Init-State.

b. Conversation termination: if the speakers have *disengaged*—for instance by means of a parting exchange, a new episode starts.

With respect to the second issue, some aspects seem fairly straightforward: we can think of the Central Executive as mapping into an Agenda (as specified in work following Larsson, 2002), specifying the next action the inputs recorded in *Pending* (M-WM: the phonological loop) and *VisSit* (M-WM: the visuo-spatial sketchpad). The guiding intuition we will employ is that the episodic buffer needs to be capacity limited, which we will construe as pertaining in a broad sense to a single eventuality. How and whether one needs to capture the four chunk constraint remains an intriguing question we cannot resolve here. A potential starting point is the model of (Takac and Knott, 2016b) concerning how events and their participants (in monological discourse) are represented in WM. A key assumption of this model is that events are experienced through sequentially structured sensorimotor routines, and similarly for the event's participants. This yields a novel mechanism for binding representations of individuals to semantic roles such as AGENT and PATIENT and directly captures capacity constraints in terms of number of event argument roles; for more on the relationship between syntax and WM see (Knott, 2012). We do address capacity constraints in one respect. We separate the speaker and addressee information, assuming current speaker is within the episodic buffer, motivated in part by data from (Alberoni et al., 1992) that suggests that Alzheimer Disease patients have difficulty tracking who is speaking, with a limit being attained at four participants. We assume that the addressee is information that arrives from the VSSP.[4]

(10) EpisodicBuffer $=_{def}$
$$\begin{bmatrix} \text{spkr : Ind} \\ \text{u-t : Time} \\ \text{c-u : speaking (spkr,u-t)} \\ \text{MaxQUD : Question} \\ \text{LatestMove : LocProp} \\ \text{TopicalFact : Prop} \end{bmatrix}$$

We will restrict attention to three fields of LTM: the first is Episodic, which we assume has a field that tracks conversational episodes; we allow that it might track other types of episodes, but do not consider how here. For a conversation in progress, it will record successive values of FACTS, QUD, MOVES, and Mood. In addition, LTM has two additional fields mentioned above: (i) Entities, which

[4]The set up here is 2 person dialogue, nonetheless, for reasons of simplicity.

keeps track of individuals with whom a given agent has familiarity, and (ii) Procedures, which stores procedural knowledge:[5]

(11) a. LTM $=_{def}$

$$\begin{bmatrix} \text{Episodic} : \begin{bmatrix}\text{Conversational} : \text{list(LDGBType)}\end{bmatrix} \\ \text{Entities} : \text{set(RecType)} \\ \text{Procedures} : \text{set(topos)} \end{bmatrix}$$

b. LDGBType $=_{def}$ $\begin{bmatrix} \text{x,y} : \text{IND} \\ \text{participants} = \{\text{x,y}\} \\ \text{Moves} : \text{List(LocProp)} \\ \text{Facts} : \text{Set(Prop)} \\ \text{QUD} : \text{Poset(Question)} \\ \text{Mood} : \text{Appraisal} \end{bmatrix}$

The partitioning of the DGB means that some conversational rules need to become more complex. We give two examples: incrementing QUD as a consequence of a query involves both updating the Episodic Buffer's MaxQUD, but also the LTM QUD. Similarly, FactUpdate/QUDDowndate requires updating TopicalFact and MaxQUD in the Episodic Buffer and the LTM FACTS and QUD:

(12) a. **Ask QUD-incrementation**:

$$\begin{bmatrix} \text{pre} : \begin{bmatrix} \text{q} : \text{Question} \\ \text{LatestMove} = \\ \text{Ask(spkr,addr,q)}: \text{IllocProp} \end{bmatrix} \\ \text{effects} : \begin{bmatrix} \text{LTM.QUD} = \langle \text{q,pre.QUD} \rangle : \\ \text{poset(Question)} \\ \text{EB.MaxQUD} = \text{q} : \text{Question} \end{bmatrix} \end{bmatrix}$$

b. **Fact Update/ QUD Downdate:**

$$\begin{bmatrix} \text{pre} : \begin{bmatrix} \text{p} : \text{Prop} \\ \text{LatestMove} = \\ \text{Accept(spkr,addr,p)} : \text{IllocProp} \\ \text{LTM.QUD} = \langle \text{p?,pre.QUD} \rangle : \\ \text{poset(Question)} \end{bmatrix} \\ \text{effects} : \begin{bmatrix} \text{FACTS} = \text{pre.FACTS} \cup \{\text{p}\} : \\ \text{Set(Prop)} \\ \text{EB.TOPICALFACT} = \text{p} : \text{Prop} \\ \text{QUD} = \\ \text{NonResolve(pre.QUD,FACTS)} : \\ \quad \text{poset(Question)} \\ \text{MaxQUD} = \text{Max(QUD)} \end{bmatrix} \end{bmatrix}$$

A summary of the emerging picture is provided in Fig. 3.

[5]For structure within episodic memory, see Takac and Knott (2016a) which describes a neural network model of episodic memory and its interfaces to entity representation in WM and LTM.

We start with conversation initialization, focussing solely on LTM. If A and B have just started a conversation, their LTM will have the form in (13)

(13)
$$\begin{bmatrix} \text{Episodic.Conversational} = \\ \left\langle \begin{bmatrix} \text{x} = \text{A} \\ \text{y} = \text{B} \\ \text{participants} = \{\text{A,B}\} \\ \text{Moves} = \langle \text{Greet(A,B)} \rangle \\ \text{qud} = \langle \rangle \\ \text{facts} = \text{cg1} \end{bmatrix}, \ldots \right\rangle \\ \text{Entities} = \text{entset} \\ \text{Procedures} = \text{procset} \end{bmatrix}$$

We now illustrate the interaction between the EB and LTM in this set up with the examples in (14):

(14) a. A: I see Jo. B: Right.

b. (A and B watching Vladimir Putin on tv walking in a hospital wearing a yellow Hazmat suit)[6] A: laughs. B: laughs.

Consider how B might process 'I see Jo': upon perception the locutionary proposition (15) updates the phonological loop—we abstract away for now from issues of lexical access. This leaves four contextual parameters to be resolved. The value for 'I' and for the utterance time are to be found in the episodic buffer, while we assume the VSSP to be the described situation; 'Jo' is found in LTM.Entities. This updated locutionary proposition then updates EB.LatestMove. Subsequently, CE—fed by LTM.Procedures—updates Agenda with the action Ground(LatestMove). This, in turn, gives rise to B's utterance whose contextual parameters are Pending.sit and B found in the VSSP:

(15)

[6]From https://abcnews.go.com/International/putin-dons-hazmat-suit-russia-admits-virus-numbers/story?id=69768452, last accessed at 10th May 2020.

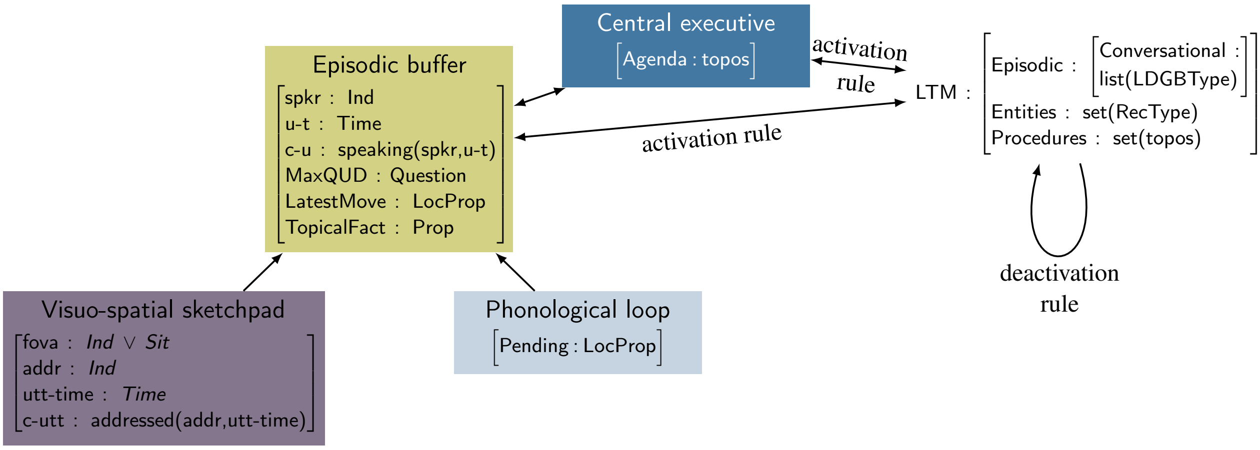

Figure 3: Fusing M-WM and DGB, and adding LTM.

$$\left[\begin{array}{l}
\text{sit} = \left[\begin{array}{l}
\text{phon} = \texttt{aysijo} \\
\text{cat} = \text{V[+fin,+root]} \\
\text{constits} = \left\{\text{ay,si,jo}\right\} \\
\text{dgb-params} = [\,] \\
\text{cont} = \left[\begin{array}{l} \text{sit} = \text{s0} \\ \text{sit-type} = \text{See(j,t0)} \end{array}\right]
\end{array}\right] \\
\text{sit-type} = \left[\begin{array}{l}
\textsc{phon} : \texttt{I see Jo} \\
\textsc{cat} = \text{V[+fin,+root]} : \text{syncat} \\
\text{constits} = \left\{\text{I, see, Jo}\right\} : \text{set(sign)} \\
\textsc{dgb-params} : \left[\begin{array}{l}
\text{s0: SIT} \\
\text{spkr : IND} \\
\text{addr : IND t0: TIME} \\
\text{c2 : addressing(spkr,addr.t0)} \\
\text{j : IND} \\
\text{c3: Named(j,jo)}
\end{array}\right] \\
\text{cont} = \left[\begin{array}{l} \text{sit} = \text{s0} \\ \text{sit-type} = \text{See(spkr,j,t0)} \end{array}\right] : \text{Prop}
\end{array}\right]
\end{array}\right]$$

Turning now to A and B sitting on couch watching Putin on tv in a Hazmat suit. A laughs. The laugh updates B's phonological loop with a locutionary proposition akin to (15) *mutatis mutandis*—the content is as given in (16). In this case the contextual parameters are A, the laughable l, and the topos τ. A and l can be instantiated from the EB and the VSSP, whereas τ involves a call on LTM.FACTS (e.g., the topos *Presidents wear formal suits*). Given this resolution, the VSSP can be appraised as pleasant, thereby updating her private Mood. Subsequently, CE—fed by LTM.procedures—updates Agenda with the action Accept(LatestMove). This, given B's Mood update, licenses B's laugh, which in turn triggers an update of her public Mood.

(16) Assert(A, Incongruous(l,τ))

We now consider a case that emphasizes one significant innovation of this set up, namely postulating that QUD is part of LTM and solely MaxQUD is part of the episodic buffer. Consider (17). Here the question (1) becomes EB.MaxQUD, but when (2) is asserted (2)? becomes EB.MaxQUD, whereas QUD now consists of both (1) and (2); after A's utterance in (3), (3a)? and (3b)? successively become EB.MaxQUD, whereas LTM.QUD consists of all four questions. Once B accepts (3), this updates both FACTS and TOPICALFACT with (3b) and makes (1) EB.MaxQUD as well as the sole member of LTM.QUD:

(17) a. A(1): Who's a good candidate?
B(2): Petra.
A(3): (3a) No, (3b) Pauline is.
B(4): OK.

3.2 Episodic and Entity activation and deterioration

We hypothesize that relational episodic traces, which we identify with TTR propositions (and potentially neurally implemented as explicated in Cooper, 2019) arise as a consequence of activation occurring during e.g., propositional acceptance. These, in turn, via projection operations on fields in the record type, construct entity traces.

Given any proposition in FACTS with x : IND fields, increment entities with record types for that individual. For instance (18a) will give rise to the entity in (18c), constructed from the type in (18b):

(18) a. A: What happened yesterday? B: A Mexican guy named Ramon killed Trotsky.

b. RamonM = $\left[\begin{array}{l} \text{x : Ind} \\ \text{c1 : mexican(x)} \\ \text{c2 : named('Ramon',x)} \end{array}\right]$

c. $\left[\text{z = RamonM : IND} \right]$

We can equally model memory deterioration operations: for neurotypicals occurring as result of underactivation, for dementives punctually and randomly as result of lesion or other mal-events. For relational episodic traces these involve elimination of fields from a record type constituting an event trace, for entity traces their downdating from Entities.

4 Laughter, memory, emotion: sample analyses

We now return to consider some of our initial examples.

4.1 Memory failure laughter

Consider (1a) repeated here as (19):

(19) NURSE: strain at a gnat and, (0.5 sec) PATIENT: (ah) (0.8 sec) *nothing else* [heh heh heh] NURSE: strain at a gnat and swallow a camel. (Lindholm, 2008, ex. (2))

The patient has in the phonological loop the locutionary proposition associated with the Nurse's utterance u_{N1}. Lexical (or collocational) access problems give rise to the issue *What word follows* u_{N1}*?* By articulating the filled pause the patient causes this question to become MaxQUD (see (8d) above). Given his continued collocational access failure, he responds to this question negatively. This failure makes the patient feel uncomfortable—laughter will help smooth the situation. Concretely, then, the laughable in this case is the collocational access failure which clashes with the topos in Agenda (When A asks a question B answers it), hence the incongruity.[7] This is an instance of laughter whose generation/resolution makes no appeal to episodic memory, and is therefore quite available to a dementia sufferer. We do not have here data on *failed* laughter triggers in dementia; see (Baumgartner and Renner, 2019) for some discussion of humour failure in dementia.

[7]Another alternative, suggested to us by Alistair Knott, is that the incongruity is a direct consequence of the inability to complete the self-repair. This is a plausible alternative in that laughter often occurs in self-repair situations and would equally not make any appeal to episodic memory for resolution.

4.1.1 Stimuli merge

The CE is the 'attentional homunculus' of the M-WM. Among others, it is responsible for focusing or dividing attention (cf. Sec. 1). According to neuropsychological evidence, items in the object of attention (of mammals) are represented in the prefrontal cortex (Güntürkün, 2005). Initiating and maintaining items within attention is driven by dopamin release (Rose et al., 2010; Lohani et al., 2019). Sustaining activations in the prefrontal cortex with dopamin excitation keeps the focus on the items associated with the activation patterns. Dopamin innervation, triggered, e.g., by concurrent representation from the VSSP via the EB or the LTM, can lead to a shift in the focus of attention. If this shifts happens during other short-term processes such as topos rehearsal, an interference of focused items can be a consequence (for a model, see (Manohar et al., 2019)). Such a dopamin-driven interference can give rise to a stimuli merge like the pipe/apple blend of an eating and a music playing situations (both staged in the VSSP) reported in example (3) in Sec. 1, since 'results from work in schizophrenia, PD, and ADHD patients point to an abnormal DA transmission as being responsible for behavioral deficiencies in some learning and memory tasks that depend heavily on PFC function'[8] (Puig et al., 2014, 4).

4.1.2 Resumed conversations

Consider again example (5), repeated here as (20):

(20) A: How can we solve the equation? B: I'll have to think about it, but now I have to run.
(3 days later) A: So? /Where were we? B: Right, yes,um I'd say just integrate three times and . . .

The initial conversation ends with a non-empty QUD. A's initial utterance in the subsequent conversation makes reference to the previous conversation, which is stored as an episode in the interlocutors' LTM, with its final state consisting of *inter alia* the non-empty QUD, which happens to be also MaxQUD. Hence, she can address this issue directly, using MaxQUD to resolve the non-sentential utterance.

[8]Abbreviations: PD = *Parkinson's disease*, PFC = *prefrontal cortex*, ADHD = *attention deficit hyperactivity disorder*.

5 Conclusions and Future Work

In this paper we have moved towards embedding dialogical semantics within neurologically well established memory systems. We have embedded certain very transient aspects as components of an M-WM style working memory. We have also sketched how to embed dialogues globally within LTM.

Both moves constitute a first step towards enabling semantics to model issues pertaining to memory problems, which occur both to dementia sufferers and to neurotypical speakers. The latter has the important consequence of enabling reference to entire conversations and to capture phenomena related to resumption and recurrence across conversations. In both areas there are a variety of hypotheses to be tested: for WM these include the question whether patients suffering from dementia can deal with stacking in QUD, a phenomenon making intrinsic use of binding into LTM. For LTM it raises the issue of testing the reality of long distance ellipsis in resumed conversations.

A much longer term challenge is to try to map the posited structures to brain structures, as is done, for instance, in models like MUC (Hagoort, 2016). Baddeley (2012) cautions against this, however, given current imaging *know how* and given the fact that a given memory structure is often apparently distributed across multiple brain structures.

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