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On the Development of Episodic Memory: Two Basic Questions

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Abstract

In this focused review we present and discuss two basic questions related to the early development of episodic memory in children: (1) "*What is an episode?"*, and (2) *"How do preverbal children recall a specific episode of a recurring event?*" First, a brief introduction to episodic memory is outlined. We argue in favor of employing a definition of episodic memory allowing us to investigate the development of episodic memory by purely behavioral measures. Second, research related to each of the two questions are presented and discussed, at first separately, and subsequently together. We argue and attempt to demonstrate, that pursuing answers to both questions is of crucial importance – both conceptually and methodologically - if we are ever to understand the early development of episodic memory.

On the Development of Episodic Memory: Two Basic Questions

1. Introduction

The present article concerns the earliest ontogenetic development of episodic memory. We will present and discuss two questions which we consider to be of crucial importance if we are to understand the earliest ontogenetic development of episodic memory. The first question is "*What is an episode?",* and the second is: *"How do preverbal children recall a specific episode of a recurring event?*" We begin by outlining the background for the latter question.

Until the beginning of the 1980[ies], Developmental Psychology was characterized by the central tenet that young children's memory was radically different from adult memory (Nelson, 1986; Nelson & Gruendel, 1981). Following the Piagetian view (Piaget, 1952, 1954) it was widely accepted that young children´s memories should be considered idiosyncratic, disorganized, and poorly structured, and therefore impossible to retain and recall after a delay.

Groundbreaking work conducted by Katherine Nelson and colleagues (Nelson, 1986; Nelson & Gruendel, 1981; Nelson & Ross, 1980) markedly changed this perspective. When asking children to report what usually happens in familiar events such as going to McDonald´s, grocery shopping, or having a birthday party, they found that children as young as three years of age indeed were able to provide accounts of script-like events following a certain structure and order (Nelson, 1986; Nelson & Gruendel, 1981). Although the children's memories of scripted events – contrary to earlier beliefs – appeared similar in kind to those of older children and adults, their memories still showed characteristic differences relative to those of adults: Even when asked explicitly about unique incidents of a scripted

event, the young children typically used impersonal pronouns and timeless present tense, *"you do X"*, instead of personalized and particularized accounts (Fivush, 1984, 1997; Hudson, Fivush, & Kuebli, 1992; Nelson & Gruendel, 1981). Consequently, the development of episodic memory as well as children's memory for recurring events seem paradoxical: Why do young children tend to recall and report recurring events based on general event knowledge instead of reporting the specific details constituting this schematized knowledge? This is especially surprising, since we know that children are capable of representing a recurring event as both an episodic memory, and as a script (Hudson et al., 1992). We believe that recall of a distinct episode and recalling a schematized version of a recurrent event are two sides of the same coin. In order to recall a unique episode (e.g., "At what time did I lose my purse last night at the restaurant?") we typically rely heavily on scripted knowledge (e.g., that you usually pay after having eaten, and just before you leave the restaurant). Meanwhile, scripted knowledge would never materialize without the existence of distinct episodes, because the latter simply constitute the basic building blocks of the former.

Even though substantial attention was paid to this question in the 1980[ies] and the 1990[ies], the interest seems to have declined. To understand the development of episodic memory, we believe that the aforementioned paradox calls for further research. In the present article we therefore attempt to revitalize this enigma.

Consider the term 'episodic memory'. When consulting any basic book on memory it becomes apparent that the 'memory' part of episodic memory has been relatively thoroughly investigated. Sophisticated theories of different *storage* systems have been developed (e.g., LTM, STM, WM). Analogous, there exists elaborated accounts of the different kinds of *knowledge* systems that human beings might possess (e.g., explicit and implicit memory and

all the subsections related to these). We also have detailed outlines of the *processes* that might be related to the act of memory (e.g., encoding, consolidation, and retrieval). Compared to this, surprisingly little attention has been devoted to the first word in 'episodic memory', and the question regarding what an episode or an event actually *is* seems to have been almost neglected. Already in 1985 this problem was stressed by Stern (1985, p. 95):

> "The basic memorial unit is the episode […]. The exact dimensions of an episode cannot be specified here; they represent an ongoing problem in the field."

Being able to single out 'an episode' must logically precede the ability to form episodic memories. If an adult or a child were unable to demarcate an episode, then the encoding and subsequent retrieval of an episodic memory would become a truly mysterious process. Meanwhile, the scientific community has been close to silent about this potential problem (for a recent exception, see Ezzyat & Davachi, 2011). Recent theoretical advances by Zacks and colleagues (Kurby & Zacks, 2007; Zacks, 2010; Zacks & Swallow, 2007) framed under the term *Event Segmentation Theory* (EST) may shed renewed light on this hitherto neglected issue. Even though EST originates from adult cognitive psychology, we believe that this approach may provide a promising framework for understanding the *development* of episodic memory as well.

Several other topics and research domains, than the two highlighted here, influence the development of episodic memory. There is no doubt that for instance brain development and the socio-cultural context, just to mention two, do have an important impact on the development of episodic memory. However, due to space restrictions we are forced to keep a more narrow focus.

The paper is structured in the following manner: First, a brief introduction to the field of episodic memory will be presented. Secondly, we present an overview of EST, and the third section concerns children's ability to remember specific episodes of recurring events. The fourth and final section is a general discussion where the presented issues and how they might influence each other will be discussed. We shall argue that further research in the two highlighted domains would facilitate our understanding of the development of episodic memory.

2. Episodic memory

The definition of episodic memory has changed over time, since Tulving (1972) introduced the term. According to Tulving's (1972) original definition, episodic memory concerned specific personally experienced events that occurred at a certain place at a certain time, emphasizing the *what, where* and *when* dimensions of episodic recall. However, it soon turned out that the original definition suffered from the problem that one could in principle recall each of the 'what', 'where', and 'when' components by means of semantic memory without actually recalling the specific to-be-remembered event. For example, most people know that they were born ('what') in a certain city ('where') on a specific date ('when'), but it is highly unlikely that they are actually capable of recalling their own birth (Columbo & Hayne, 2010). In order to remedy this flaw, Tulving (1985) subsequently tied episodic memory to a specific kind of conscious experience, the so-called *autonoetic consciousness*. Autonoetic consciousness refers to the phenomenological sense of experiencing yourself being present at the time when the to-be-remembered episode originally took place. Besides solving the aforementioned problem with semantic memory as a potential confounder, this change in definition had at least two additional advantageous consequences. First, relating episodic memory closely to autonoetic consciousness, emphasized the phenomenological

qualities (e.g., vividness) accompanying the original experience. This led to an increase in the face validity of the concept episodic memory – at least as long as the remembering subject is an adult human being. Second, focusing on the subject's ability and experience of travelling mentally through time, paved the way for the possibility of exploring mental time travel not only back in time, but also to envision future scenarios (e.g., Suddendorf & Corballis, 1997, 2007). A natural consequence of these conceptual developments was that several researchers (e.g., Roberts, 2002; Suddendorf & Corballis, 1997), including Tulving (2002) himself, came to endorse the claim that episodic memory may not only be a late developmental achievement, but also a uniquely human feature.

The proposed strong association between episodic memory and autonoetic consciousness may, however, also have drawbacks: First, consciousness may be among the *least* clearly understood phenomena within the cognitive sciences (Crick, 1994; Dennett, 1991). Quite surprisingly, the potential problems caused by making a vaguely defined concept a crucial part of the definition of episodic memory have not received much attention. Second, consciousness is cumbersome, if not impossible, to investigate by means of purely behavioral measures. Hence, it becomes very difficult to investigate episodic memory in non-verbal species, leaving the bold claim that episodic memory is uniquely human an almost self-fulfilling prophecy (Clayton, Griffith, & Dickinson, 2000; Columbo & Hayne, 2010).

Consequently, when investigating episodic memory in non-human animals, comparative psychologists have argued in favor of using the term 'episodic-like memory' or www-memory based on Tulving's (1972) original definition of episodic memory. Episodic-like-memory' is defined as the ability to recall 'what', 'where', and 'when' information about an event – even though one cannot rule out the possibility that 'episodic-like memory'

might be re-constructed by means of semantic memory (Clayton & Dickinson, 1998; Clayton, Griffith, Emery, & Dickinson, 2001; Clayton & Russel, 2009; Martin-Ordas, Haun, Colmenares, & Call, 2010).[1] The main argument for using the terms 'episodic-like memory' or www-memory in the investigation of the development of episodic memory is the need for a concept allowing for empirical investigations by means of *behavioral* measures.

At the time of writing, the scientific community has not yet reached consensus regarding which criteria to employ when investigating episodic memory by purely behavioral measures (Columbo & Hayne, 2010). However, if episodic memory indeed is a late developmental achievement primarily, or only, evolving in human beings, it becomes even more important to understand the developmental course of the phenomenon at stake. No one would assume that a child wakes up on his or her, say, fifth birthday capable of having episodic memories, without having been able to manifest at least *some* aspects of episodic memories earlier in life. This also implies that some components of episodic memory (e.g., the 'when' aspect) may be late developmental achievements (McCormack & Hoerl, 1999). Recent evidence is in accordance with this claim (Hayne & Imuta, 2011; McCormack & Hoerl, 2007). For example, in a hide-and-seek task 3-year-old children were able to recall in what room ('where') three toys ('what') had been hidden, but unlike their 4-year-old peers, the 3-year-olds had difficulties recalling the order ('when') in which the objects had been hidden (Hayne & Imuta, 2011). Thus, there is every reason to believe that the ability to recall specific episodes starts early in life and develops over time. Consequently, the present authors believe that to understand how episodic memories evolve early in the ontogenesis, we simply have to make use of a conceptual vocabulary allowing us

[1] For another recent approach to a behaviorally based definition of episodic memory, see Russel and Hanna (2012).

to consider, analyze, and investigate potential precursors to episodic memory by behavioral means.

3. Event Segmentation Theory

To fully comprehend the development of episodic memory it seems central to ask: *What is an episode?* As already mentioned this question has for a long time been relatively overlooked. In everyday conversations it may not seem a huge problem not to have a clear definition of an event or an episode, because adults are able to align their understandings of events simply by talking about them. However, when studying infants or children, discussing different understandings of events is clearly not always an option. Thus, in order to investigate the development of episodic memory, it seems mandatory to seek a clearer definition of the *episode* in episodic memory.

Recently, Zacks and colleagues developed a theory investigating what an episode or an event is: Event Segmentation Theory (EST) (Kurby & Zacks, 2007; Zacks & Swallow, 2007). Although this theory originates outside classical memory research, we consider it to be a promising platform for investigating events as such. We therefore take the liberty to present the theory in some detail. EST investigates the fact that people automatically seem to make sense of an otherwise chaotic and dynamic world by parsing perception streams into identifiable parts (Kurby & Zacks, 2007; Zacks, 2010). Event segmentation has been studied for several years (e.g., Newtson, 1973) primarily with a focus on perception. Recently however, there has been an increased interest in other areas such as learning, problem-solving, and memory (e.g., Kurby & Zacks, 2007; Radvansky, 2012; Speer & Zacks, 2005; Swallow, Zacks & Abrams, 2009; Zacks, Speer, Vettel, & Jacoby, 2006). In order to explore how EST relates to memory, this section begins with a general description of EST, followed

by a section on event segmentation and memory and a section concerning event segmentation in infancy.

In EST an event is defined as a segment of time at a given location conceived by an observer to have a beginning and an end (Zacks & Tversky, 2001, p. 2). Zacks and colleagues have primarily focused on everyday events lasting a few seconds to tens of minutes (Kurby & Zacks, 2007). Furthermore, they have only explored goal-directed human activity, as opposed to purely physical events (e.g., event categorization, Baillargeon & Wang, 2002).

Event segmentation is conceived as a natural and effortless part of everyday perception and comprehension, probably deriving from an adaptive mechanism allowing us to integrate information from the past in order to improve and adjust predictions about future events (Kurby & Zacks, 2007; Zacks, 2010). Event segmentation allows people to transform sensory input into representations, making it possible to create predictions about the future, enabling us to act proactively (Zacks, Speer, Swallow, Braver, & Reynolds, 2007; Zacks, Kumar, Abrams & Mehta, 2009). Event segmentation is thus described as the process by which people automatically parse a continuous stream of activity into meaningful events thereby making it possible to understand an extended time period as a single chunk (Zacks & Swallow, 2007).

According to EST, people spontaneously employ perceptual information to build mental models of the current situation – *event models* – creating an understanding of "what is happening now?" (Swallow et al., 2009). These models consist of current perceptual input as well as earlier acquired semantic knowledge and function as working memory representations. They can thus be considered as multimodal, integrating information from

several sensory modalities (bottom-up), as well as influenced by input from event schemata and scripts (top-down) (Zacks et al., 2007).

Event models predominantly give accurate predictions, and as long as the models reflect the current situation, they stay relatively stable (Zacks et al., 2007; Kurby & Zacks, 2007). As soon as the prediction errors increase, often induced by a change (e.g., the completion of a goal), a gating mechanism opens allowing the models to be reset and rebuild to fit the current situation. Updating event models leads to an increase in processing causing a more robust encoding of the information present at that time (Kurby & Zacks, 2007). The models then enter into a new stable state.

The periods of time characterized by an increase in processing are also called *event boundaries*. Event boundaries often occur during periods of change e.g., induced by goal-completion, since this increases the risk for prediction errors (Zacks, 2010; Kurby & Zacks, 2007). When watching someone doing the dishes it may be pretty easy to predict the next step in the activity: First you wash the plates, and then you dry them. However, completion of each minor step complicates the prediction of the next step. After the updating period a new segment begins. Boundaries can be identified in a bottom-up fashion based on sensory characteristics (e.g., movement changes) and in a top-down fashion based on knowledge structures (e.g., changes in intentions or goals) (Zacks, 2004).

According to EST, people also segment activity at multiple timescales as well as hierarchically into parts and sub parts often organized by recognition of goals and sub goals (Kurby & Zacks, 2007; Zacks & Swallow, 2007). People thus divide activities into coarse-grained as well as fine-grained events allowing them to make different impressions depending on the grain at which they segment the activity (Kurby & Zacks, 2007; Zacks et al., 2007). Observing someone cooking dinner one may divide the activity into coarse-

grained events such as getting the ingredients and preparing the meal. Whereas one may also describe it in terms of more fine-grained events such as getting each ingredient, adding them in a particular order, adding spices and so forth.

Event segmentation is influenced by generalized knowledge (e.g., scripts and schemata, Kurby & Zacks, 2007), allowing people to employ knowledge from previously encountered activities to comprehend a current activity. Event schemata and scripts may thus play a critical role in guiding segmentation (Zacks & Tversky, 2001; Zacks et al., 2006).

Event segmentation has been studied primarily by use of a procedure developed by Newtson and colleagues (e.g., Newtson & Engquist, 1976). In this procedure participants are asked to press a button whenever they judge a meaningful event ends and another begins (event boundaries) (Newtson, 1973; Newtson, Engquist, & Bois, 1977). This paradigm has been widely supported and people seem to be highly consistent in their judgments (Zacks & Swallow, 2007). In general event segmentation tasks seem to have high intersubjective agreement and reliability. Besides using explicit behavioral measures, event segmentation has also been investigated by means of more indirect measures such as implicit behavioral measures and neuroimaging studies (Kurby & Zacks, 2007; Zacks & Swallow, 2007).

3.1 EST and Memory

According to EST it is essential how people segment activity since it affects what they remember from an event (Zacks & Swallow, 2007; Zacks et al., 2006). As previously mentioned, event boundaries are characterized by an increase in processing leading to a more detailed encoding of information present at that time, hence also to better recall of items visible at boundaries. This assumption has been supported by several studies (e.g., Newtson & Engquist, 1976; Schwann, Garsoffsky, & Hesse, 2000), and according to Kurby and Zacks

(2007) segmenting events effectively thus leads to better memory. However, identifying the wrong events may lead to poor memory and learning (Zacks & Swallow, 2007).

Swallow et al. (2009) have investigated how event boundaries may affect memory encoding and updating. The studies strongly suggest that objects presented at event boundaries are better recognized compared to objects presented at other times. Moreover, they found that the ability to recall recently encountered objects change during segmentation, since crossing event boundaries affects how earlier acquired information is retrieved. Besides showing that long-term memory primarily consists of information present at event boundaries, they also found that this information is highly conceptual in nature. Event segmentation should thus affect which information is encoded as well as the accessibility of that information. According to Swallow et al. (2009) the event boundaries people perceive will then become boundaries for their memories as well. Segmentation is therefore thought to play a pivotal role in our ability to remember and learn from events.

3.2 Event Segmentation Skills in Infancy

So far only a few studies have been published concerning infants' ability to segment events involving human action (e.g., Baldwin, Baird, Saylor & Clark, 2001; Friend & Pace, 2011). However, the idea of investigating event segmentation by means of perceptually-driven stimuli seems to be an advantageous foundation for developing methods suitable for preverbal children. Furthermore, investigating segmentation skills in infancy seems to be of great importance in order to understand the development of these skills and to explore how infants segment events without as well as during the acquisition of more highly advanced event knowledge such as a richer understanding of mental states (Meyer & Baldwin, 2011). Researchers in this area have primarily used nonverbal looking time methodologies, like

familiarization, cross-modal matching paradigms and habituation (e.g., Baldwin et al., 2001; Saylor, Baldwin, Baird & LaBounty, 2007).

Generally these studies have shown that infants and young children do possess some segmentation abilities (Kurby & Zacks, 2007). Baldwin et al. (2001) found that infants (10-11 months-old) after a familiarization period were able to detect disruptions in videos of everyday actions and thus parse behavior according to intentional action. The children watched videos demonstrating everyday events (e.g., picking up ice cream) for a familiarization period, followed by a version of the movie with still-frame pauses inserted. For one group the pauses were inserted at points *coinciding* with the completion of intentional actions, and for the other group they were inserted at points *interrupting* such completion. The fact that the infants reacted with surprise (longer looking time) to the interrupting movies compared to the completing test-videos was interpreted as that the children were able to parse or segment behavior according to intentional behavior.

In order to help determine whether young children can segment everyday activity as it unfolds before their eyes without prior practice, Saylor et al. (2007) replicated these results without the familiarization period. This study demonstrated that 9- to 11-month-old infants do indeed parse action in a more "on-line" fashion. Friend and Pace (2011) also found that 22- to 29-month-old children spontaneously segmented events. When prompted to re-enact a single action from a previously demonstrated three-step live event, the children did show sign of event segmentation capabilities. At no time did any of the children produce only a part of an action or an action transition, suggesting that they segmented the event at coarse-grained action boundaries. Additionally, a recent study conducted by Meyer and Baldwin (2011) showed that 3- and 4-year-olds responded to event boundaries with varying attention depending on whether it was segmented into fine or coarse-grained events. Coarse-grained

events received additional attention as well as longer processing time. Furthermore this effect was seen most strongly in the children with superior memory for the events.

Together these studies provide evidence that infants indeed are able to segment activities into smaller meaningful units when observing goal-directed human activity. These abilities become more specialized with age probably affected by a developing understanding of intentions, actions and goals (Meyer & Baldwin, 2011).

3.3 Event segmentation: Limitations and Future Directions

This section has illustrated that how we segment, understand, and define episodes, has vital consequences for our memory. Moreover, EST has provided a framework for investigating the previously mentioned question: *"What is an episode?"* from the point of view of both infants and adults, and to explore how this affects memory. The studies conducted by Zacks and colleagues suggest a strong connection between how we understand, hence segment an event, and what we remember and learn from this. Consequently, there may be various ways of segmenting events. There may be a "normative" way of segmenting events leading to a better later memory, whereas other routes may lead to a decrease in memory. Our understandings and definitions of events thus become critical predictors for what kind of information is being picked up.

The experiments conducted on event segmentation and memory raise interesting questions for further investigation: The claim that event boundaries should have a privileged status in long-term memory, suggests that our memories primarily consist of information available at periods of change and unpredictability, since information at these periods will be exposed to deeper processing and greater contact with semantic knowledge (Swallow et al., 2009). Although several explanations exist as to why this may be the case, it is still an unsolved question exactly *why* we tend to remember more from these periods (Swallow et

al., 2009). In line with this it seems relevant to investigate how the background knowledge people possess influences their segmentation of events. According to Kurby and Zacks (2007) this is an important area in need of more research, and although it remains unclear exactly how event knowledge and segmentation work together, they suggest that schemata and scripts may reduce prediction errors during perception. Further research addressing exactly how this works for infants and children, seems to be crucial for our understanding of how events and episodes are demarcated in infants and children. The fact that conceptual knowledge constituting the schemata and scripts is still under considerable development in infants and children (e.g., Mandler, 2004), further complicates the matter substantially.

The few existing studies on event segmentation in infancy show that infants do possess some segmentation skills early in life. However, the studies do not tell us much about *how* infants actually segment events, namely the process of event segmentation. Nor do they tell us much about exactly how event segmentation affects young children's memory. As previously suggested, one may suspect that compared to adults infants segment events in a different way, since they do not possess the same highly advanced conceptual knowledge. Saylor et al. (2007) furthermore add that we do not know exactly what enables infants and children to segment events according to the completion or initiation of adult-judged intentions. Clearly, research is needed in order to learn more about event segmentation in infancy and to what extent EST can account for young children as well. One potentially promising approach may be to employ eye tracking methodology which has turned out to be a strong tool for investigating the microstructures of cognition in infants (Aslin, 2007, 2012). Another way of approaching this issue may be to have a closer look at the development of scripts and schemata in young children, since this may tell us more about what kind of top-

down processes children do possess and how this affects the segmentation of events as well as later memory. This will be elaborated on in the next section.

4. Recall of a recurring event

A child´s daily life consists of many different routine events such as getting up in the morning, getting dressed, and going to kindergarten. These mundane events are typically referred to as *recurring events* (e.g., Price & Goodman, 1990). As previously mentioned, the developmental course of children's ability to remember recurring events as well as unique episodic memories represents an enigma: Why is primarily the gist of a recurring event preserved, whereas the unique events constituting the script seem to be almost forgotten? (Nelson, 1986; Nelson & Gruendel, 1981, 1986). In the following section this paradox will be presented and discussed.

4.1 General event knowledge

Memory for recurring events is often referred to as *scripts* or *generalized event representations* (Hudson & Mayhew, 2009; Nelson & Fivush, 2000). The term script, originally introduced by Shank and Abelson (1977), refers to an internal structure prescribing temporal and casual sequences of actions, actors, and props typical for a particular event. A script is a prototypical form of the general event representation, meaning that memories for scripted events are not tied to particular experiences, but represents recurring characteristics of familiar events. Scripts for recurring events thus allow children to interpret information from their everyday experiences and to predict what may happen in similar future events. Moreover, scripts also inform children what *not* to expect (Bauer, 2007). According to Nelson and Fivush (2000) generalized event knowledge is semantic knowledge and therefore contrasts with episodic memory as defined by Tulving (1972, 1985). However, general event knowledge contributes to the reconstructions of episodic

memories by providing information on main event categories (e.g., *who, what,* and *when)* in specific events (Hudson & Mayhew, 2009).

Since the seminal research by Nelson and colleagues (Nelson, 1986; Nelson & Gruendel, 1981), several studies have confirmed the basic findings, that even three-year-olds organize recall of events in general event representations (Fivush & Hudson, 1990; Hudson et al., 1992). Fivush (1984) demonstrated that even on the second day of school, children, who were asked to recount the course of a usual school day, reported this event in a generalized, temporally organized form indicating that an event representation is formed after just one experience. Note, that children tended to report in a generalized manner even when asked specifically "What happened in school yesterday?" However, data reported in the above-mentioned studies rely primarily on verbal accounts, which have been found to underestimate young children´s mnemonic competencies (Fivush, Kuebli & Clubb, 1992; Mandler, 1990; Price & Goodman, 1990). Children may thus be capable of recalling more information than they are able to report verbally.

One of the first studies contributing to the, at that time, virtually non-existing literature on event representations in children under the age of three, was conducted by O`Connell and Gerard (1985). They examined 20-, 24-, 28-, and 36-month-olds ability to recall event sequences depicting familiar events (e.g., having a snack) presented in either a canonical, reverse, or a scrambled order. The study revealed that only the 36-month-olds were able to reproduce the correct order in all three conditions leading O`Connell & Gerard (1985) to conclude that children under the age of 36-months use temporal organization qualitatively different from that of older children. Moreover, they argued that only children older than 24-months can use temporal information to guide recall of familiar event sequences. However, this claim was challenged by research by Bauer and colleagues (Bauer & Shore, 1987; Bauer

& Mandler, 1990, 1992) showing that ordered recall is facilitated by so-called *enabling relations* – even when considering infants.

Enabling relations are said to exist when one action in an event sequence is both temporally prior to and necessary for the next action in the same sequence to occur. For example mixing dough is a necessary prerequisite of baking a cake in order to eat it later on. In contrast, if there are no inherent constraints on the temporal order of the actions, the event is said to be *arbitrarily* ordered. It is for instance possible to put your hat on either before or after you put on your jacket (Bauer, 1997; Bauer & Shore, 1987; Bauer & Travis, 1993). The ability to remember arbitrarily ordered events has been found to improve with age (Wenner & Bauer, 1999) although even adults remember enabling sequences better than arbitrary ones (Bauer & Wewerka, 1997).

These results have thus questioned the interpretation originally offered by O`Connell & Gerard (1985), that infants' and young children's ability to remember events primarily depends on the *familiarity* of the event. Enabling ordered sequences are far easier to remember than arbitrarily ordered sequences (Bauer & Mandler, 1989; Bauer & Travis, 1993; Wenner & Bauer, 1999) meaning that the *relation* between the event sequences has substantial impact on children's event memory as well.

4.2 The Influence of Repeated Experience on Recall

Repeated experience with an event has been found to both distort and enhance recall of a specific event. Using Bauer´s (2007, p. 250) words, familiarity or repeated experience with a specific event seem to be a *double-edged sword* due to the ambiguous effects it can have on memory. Research conducted with children in the age range 3-to 7-year-old suggest that they have difficulties recalling details from specific episodes from highly similar events (Hudson & Nelson, 1986; Kuebli & Fivush, 1994; Ornstein 1995). With time even atypical actions

seem to be forgotten as children tend to recall information consistent with the general event schema not necessarily stated in the specific event (Hudson, 1990; Hudson & Nelson, 1986). These findings are consistent with the Event-schema theory (Hudson et al., 1992) and the Fuzzy-trace theory (Brainerd & Reyna, 2004) both suggesting that repeated experiences tend to improve memory for typical features of an event, consequently impairing the ability to recall specific details.

However, the ability to recall a specific episode of a recurring event may be strengthened by the presence of appropriate cues. For instance, Fivush (1984) found that most of the kindergarten children were able to provide additional information about a specific story when provided with the title of the book. More information thus seemed to be latently available in memory, but the activation of this knowledge was dependent on the right cues. Furthermore, research with young children reveals that verbal cues can have a similar facilitating effect on one- to two-year-olds recall of an event (Bauer, Hertsgaard, & Wewerka, 1995; Bauer, 1996; Hayne & Herbert, 2004). These results all seem to fit the prediction put forward by The Fuzzy-trace theory suggesting that general event representations of recurring events (*gist traces*) are encoded and stored independently and in parallel with surface details (*verbatim traces*) (Brainerd & Reyna, 2004). Because verbatim traces are encoded separately from the gist traces, specific details of an event can be recalled later on, as long as the trace has not decayed. These results thus suggest that cues facilitate a child´s ability to recall specific details of a recurring event.

Related to this, several studies have illustrated that experience with recurrent events can also *improve* memory both in terms of the amount of information remembered (e.g., Fivush, 1984; Hudson, 1986, 1990) and in the length of time over which the event can be recalled (Bauer et al. 1995; Fivush & Hamond, 1989). Fivush (1984) for instance found that

the amount of information kindergarten children produced in response to the question *"What happens when you go to school?"* increased from seven acts on the second day of school to twelve acts by the 10th week of school. These results thus suggest that repeated experience with an event following a script seem to affect the efficacy of recall especially over longer delay.

4.3 Age-Related Differences in Recall

In addition to repeated experiences with an event, children's event representations become more complex and elaborated with age (Fivush, 1997). Price and Goodman (1990) for instance investigated 2½- and 5-year-old children who were exposed to the same amount of experiences with a particular event (visiting a wizard). Regardless of verbal and reenactment measures, the 2½-olds reported significantly fewer components of actions from the event compared to the 5-year-olds. Similar findings are reported by Farrar and Goodman (1990, 1992).

The schema-confirmation-deployment-theory (Farrar & Goodman, 1990) provides a framework that may help capture and explain age-related differences in recall of a specific episode of a scripted event. Preverbal children, who are in the process of understanding how the world operates, are likely to pay attention to similarities across various events, trying to confirm information to their existing schemes, in order to ease the comprehension of the event (*the schema-confirmation phase).* Once a schema representation has become relatively stable due to increasing age and experience, children are able to shift focus to inconsistent schema information (*the deployment phase).* During this phase, information consistent with the schema requires limited attention releasing cognitive resources to process new and possibly inconsistent information, allowing specific memories to be formed. The results from several studies seem to support this model (e.g., Farrar & Boyer-Pennington, 1999;

Farrar & Goodman, 1990, 1992; Fivush et al., 1992; Price & Goodman, 1990). Overall, it seems that children with increasing age and experience develop more elaborated and complex event representations and that these event representations influence the development of episodic memory.

To summarize, research suggests that multiple factors known to influence recall of recurring events in older children and adults also seem to have an impact on preverbal children (Bauer, 1997; Fivush, 1997). Especially, the organization of early event representations has a pronounced effect on young children´s recall of a specific episode of a recurring event. Even upon the first experience, children seem to form a generalized event representation of this event. Moreover, enabling relations between event sequences facilitate the child's ability to recall these events even over relatively long delays, whereas arbitrarily ordered events do not. Generally, event representations become more complex with both age and experience. In addition, it seems that repeated experiences with a particular event may have both enhancing and distorting effects on memory. Preverbal children *do* retain memories of specific episodes of recurring events. However, these can be difficult to recall without appropriate cues. According to Hudson et al. (1992) it is still unknown for how long such cues are effective.

4.4 Recurring Events: Limitations and Future Directions

As illustrated in the previous section research on memory for recurring events in infancy has progressed far beyond the early work conducted by Nelson and collaborators in the 1980[ies] (e.g., Nelson, 1986), Today, we know that even infants organize knowledge about recurring events as schematized event representations. Even though event knowledge develops from relatively simple representations to more elaborated and abstracted representations as a function of increasing age and experience there seems to be a substantial

continuity in these mnemonic processes across the lifespan (Fivush, 1997). A robust finding in the literature suggests that preverbal children construct both gist and verbatim representations as a function of repeated experience (cf. the Fuzzy-trace theory).

In order to understand the developmental course of episodic memory it is important to understand the forming as well as the later accessibility of verbatim representations, since they contain information of single occurrences of a recurring event. Therefore, a future challenge may be to identify the underlying mechanisms strengthening children´s ability to maintain verbatim traces in order to keep these early memories accessible in the transition from infancy to early childhood (Bauer, 1996).

Furthermore, a number of studies have revealed that young children are confused when a recurring event varies from the typical script (e.g., Farrar & Goodman, 1990, 1992). According to Fivush (1997) it remains an open question *why* young children are confused by even minor variations of a recurring event during the first few experiences but also *how* this changes developmentally. In a similar vein Hudson et al. (1992) claim that when children experience dissimilar episodes they cannot be sure whether they have experienced two distinct events or whether they have experienced a deviation from a consistent event sequence. Related to this, it seems important to examine under which conditions a script facilitates the child´s ability to recall a specific occurrence of a recurring event as well as when it may have the opposite effect. At an even more fundamental level there is a need for more basic research on how scripts evolve in preverbal as well as in verbal children. One promising approach may simply be to teach children completely novel scripts and follow how the children subsequently employ these scripts. Another route addressing the same overall issue might be to investigate how children remember events scaffolded by either ‘weak’ or ‘strong’ scripts – as well as violations of these.

Moreover, since specific episodes also affect the formation and development of a script this is indeed also relevant to look into. A lot of research conducted on preverbal children´s recall of a specific instantiation of a recurring event has employed a between-subject-group design, but if we are to understand the developmental *course* of episodic memory it may be interesting to use longitudinal research designs.

These recommendations for future studies, although not exhaustive, highlight some of the important areas in need for further research in order to fully understand the development of episodic memory.

5. General Discussion

We have discussed two questions that we believe are important when attempting to understand the development of episodic memory: (1) *"What is an episode?"*, and (2) *"How do preverbal children recall a specific episode of a recurrent event?"* So far the contributions and limitations of each area have been discussed separately. In this final section we will discuss whether and how each of the two domains may contribute to the understanding and development of the other domain – as well as to episodic memory in the broader perspective.

How children parse a continuous stream of activity into meaningful singular episodes is bound to affect children's ability to remember *any* specific episode, and therefore also applies to specific episodes of recurrent events. Research on event segmentation amply demonstrates that both top-down processes (e.g., event models) and bottom-up processes (i.e., perceptual and sensory processes) are involved in event segmentation, and that the understanding of episodes directly affects our memory of the event. However, there also seems to be carryover effects with regard to methodology: The fact that EST makes use of visually based methodologies may offer research on children's ability to remember specific

episodes of recurrent events a powerful, and in this domain hitherto unexploited, methodological tool. For instance, one could present infants and/or young children with filmed sequences of variations of a recurrent event (e.g., being put to bed or having breakfast), while the child is being eye tracked. The combination of eye tracking and EST would provide us not only with information regarding what the child is paying attention to while encoding each unique sequence, but *qua* EST also with specific hypotheses with regard to how to test for the child's memory for such sequences at a later point in time. One crucial advantage with this visually based approach is that language constraints on the child's side is ruled out, allowing us – at least in principle – to test children at an earlier stage in development, that is, *during* the construction of the child's general event representations.

As evidenced in the section on enabling and arbitrarily ordered events, the term 'enabling' seems to cover a spectrum from genuinely causal sequences (e.g., opening a door before entering a room) to more culturally specified relationships (e.g., taking your clothes off before going to bed). The employment of visually based techniques borrowed from the event segmentation approach may provide us with a versatile methodology allowing us to investigate very specific hypotheses regarding exactly *how* different kinds of enabling relations and also arbitrarily ordered relations may be processed in children.

Moreover, research on children's ability to remember specific episodes from recurrent events may offer substantial and important contributions to the further development of EST. Because EST is primarily a theory of how *adults* automatically parse a continuous stream of activity into meaningful events, the theory's account of the origin of *event models* appears to be somewhat insufficient from a developmental perspective. The departure point seems to be that adults simply *have* event models. However, infants and children do not possess fully fletched event models or general events models as they are called in the developmental

literature; they have to be build-up. In our opinion, Farrar and Goodman's (1990, 1992) schema-confirmation-deployment-theory may offer the currently most promising theoretical framework for understanding the construction and employment of schematic knowledge in children. For instance, their account of the *process* by which children look for similarities across various events attempting to build up schemes during what they call the schema-confirmation phase is much more detailed and comprehensive compared to what is found within EST. Further, in case a child fails to pay attention to details that is *in*-consistent with the event model that the child is assumed to use in a given EST study, then the schema-confirmation-deployment-theory predicts that the child's current event model has not yet been firmly established (Farrar & Goodman, 1990). In short, Farrar and Goodman's (1990, 1992) theory provides a promising framework in order to understand the process by which the event models in EST *develop* during infancy and early childhood.

Within research on children's ability to recall specific episodes using the deferred and elicited imitation paradigm a few studies have attempted to *combine* these methodologies with children's verbal accounts of the same stimulus material (e.g., Bauer, van Abbema, Wiebe, Cary, Phill, & Burch, 2004; see also Simcock & Hayne, 2002, 2003). Although this strategy may only be employed effectively within a restricted age range, it seems worthwhile to exploit further (Suddendorf & Busby, 2003). Actually, the scope may be even broader: Considering an enigma like childhood amnesia – the phenomenon that adults have very few, if any, recollections from their first 3-4 years of their lives (e.g., Bauer, 2007; Hayne & Jack, 2011; Pillemer & White, 1989) – it seems thought provoking that so few studies hitherto have attempted to exploit the possibilities of extracting and comparing behavioral and verbally expressed measures derived from the same to-be-remembered material. This approach may not only be promising within imitation paradigms, but may also be applied

within the EST domain. One might for instance investigate how young children in different age groups segment scripted events by means of *both* visually based eye tracking methodology *and* verbal reports on the same stimulus material. Although no such studies, to the best of our knowledge, have been conducted at the time of writing, we speculate that such studies could potentially provide insights regarding *when* and *to what extent* implicit and explicit event segmentation converges during development.

Let us consider the potential consequences of the insights presented here for our understanding of episodic memory in a broader perspective. If episodic memory is to be considered closely connected to autonoetic consciousness (Tulving, 1985, 2002), then the development of autonoetic consciousness in infants and children requires much more careful attention from developmental psychologists than is currently offered. However, this issue is far beyond the focus of the present article, and we have already raised our concerns in this regard. Although there appears to be no widely accepted behavioral test for the less advanced 'episodic-like memory', we maintain that this is an important approach when attempting to understand the *development* of episodic memory. In this regard it seems mandatory to carefully consider the *relative* weight of each of the w-dimensions and how they come into play developmentally. First, there seems to be no doubt that the *when*-aspect comes in place relatively late in development (e.g., Hayne & Imuta, 2011; McCormack & Hoerl, 2007) – this is especially the case if we are talking about a full blown understanding of the *when*-aspect where the subject indeed is capable of deciding when a given episode took place. The understanding of time requires not only a fairly mature cognitive system but also considerable culturally inherited tools like semantic knowledge on time concepts, seasons, and calendars (e.g., Friedman, 2005).

However, it is not only the *when*-dimension that is influenced by semantic knowledge. This is clearly also the case for the *what*-aspect. Categorizing a given incident as belonging to for instance the shopping-event category is dependent on semantic knowledge (Suddendorf & Busby, 2003). This issue may seem trivial considering episodic memory in adults, but becomes crucial when considering infants and children for whomschematic and scripted knowledge goes through substantial changes during the ontogenesis. Furthermore, these considerations underscore the complicated interplay and interdependence between specific episodes and recurrent events.

Episodic memory has become a central term within the memory literature. Our memories are not only important with regard to identity formation; they also help making decisions and guide our attempts to prepare for distant future scenarios (Bauer, 2007; Howe, 2011). If we are really to understand episodic memories as such, we need to understand the phenomena as it evolves during the ontogenesis. We hope to have shown that further research on event segmentation and memories for specific episodes of recurrent event, as well as the interplay of these domains will facilitate this interesting enterprise.

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