Schema and deviation effects in adults' memory for repeated events

by

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Thesis submitted in partial fulfilment of the requirements for the award of the degree of Doctor of Philosophy of the University of Portsmouth

June 2020

For Tomáš, and also Ráchel and Amos, who came along the way.

Declaration

Whilst registered as a candidate for the above degree, I have not been registered for any other research award. The results and conclusions embodied in this thesis are my work and they have not been submitted for any other academic award.

Word count: 32 210

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Acknowledgements

I would like to thank all the advisors and colleagues who supported me throughout this journey. James, Hartmut, Ryan, and Jonathan provided me with advice and feedback, challenged me when they believed I could do better, and supported me when I lacked confidence. They helped make my PhD a wonderful learning experience and I am grateful for having the opportunity to work with them.

This research would not happen without the support of my husband Tomáš, who believed that pursuing this dream was worth it, and who was by my side every step of the way. I am also grateful for the support of my parents and friends. The final year of my PhD would be much harder without my father's help with care for our two children.

All the students who assisted at data collection and coding and all the research participants deserve a special thanks; carrying out this research would not be possible without their help. Finally, I would like to thank the Faculty of Science, University of Portsmouth, who funded my PhD, the International Centre for Research in Forensic Psychology, who funded my research visit with Heather, and the Society for Applied Research in Memory and Cognition, who provided grant funding for my final study.

Dissemination

Publications

Rubínová, E., Blank, H., Koppel, J., & Ost, J. (in press). Schema and deviation effects in remembering repeated unfamiliar stories. *British Journal of Psychology*. https://doi.org/10.1111/bjop.12449

Rubínová, E., Blank, H., Ost, J., & Fitzgerald, R. J. (2020). Structured word-lists as a model of basic schemata: deviations from content and order in a repeated event paradigm, *Memory*, *28*, 309-322. https://doi.org/10.1080/09658211.2020.1712421

Conference presentations

Rubínová, E., Ost, J., Blank, H., & Fitzgerald, R. J. (2015, June). *Remembering schematic repeated events: Minor changes of content and order differentially affect recall*. Paper presented at the biennial meeting of the Society for Applied Research in Memory and Cognition, Victoria, BC.

Rubínová, E., Ost, J., Blank, H., & Fitzgerald, R. J. (2016, July). *Deviations from a schema: Effects of changes of content and order on remembering repeated events*. Paper presented at the International Conference on Memory, Budapest, HU.

Rubínová, E., Ost, J., Blank, H., & Fitzgerald, R. J. (2019, June). *Remembering stories: Schema and deviation effects in a repeated event paradigm*. Paper presented at the biennial meeting of the Society for Applied Research in Memory and Cognition, Brewster, MA.

Rubínová, E., Ost, J., Blank, H., Fitzgerald, R. J., & Price, H. L. (2019, June). *Remembering instances from a repeated event: What happens when one instance differs in content or order of actions?* Paper presented at the biennial meeting of the Society for Applied Research in Memory and Cognition, Brewster, MA.

Rubínová, E., Ost, J. Blank, H., Fitzgerald, R. J., & Sauer, J. D. (2015, March). *Remembering schematic repeated events: Do we remember when routines change?* Poster presented at the International Convention of Psychological Science, Amsterdam, NL.

Abstract

In this thesis, I present research that investigated schema formation and schema-deviation effects in memory for instances of a repeated event. In five experiments, samples of adult participants repeatedly encountered stimuli that were intended to establish a schema in terms of units of *content* occurring in a specific *temporal order*. As the complexity of stimuli across experiments increased, this schema was operationalized as a sequence of word-categories in a list, actions in an unfamiliar story, or activities experienced during a visit. Each aspect of the schema—content and order—was then systematically violated by introducing deviations in the final instance of the repeated event. To examine potential deviation effects on memory for the whole repeated event, participants were asked to recall all instances. The findings indicated that content and order deviation effects are qualitatively different, and that (any) deviation effects likely depend on the level of schema formation and on the degree to which a deviation is noticed. Specifically, a content deviation within an instance of a repeated event for which a schema is developed is likely to be noticed, well remembered, and may result in better recall across all instances. By contrast, due to the implicit nature of the order aspect of a schema, an order deviation may not be noticed but may result in disruption of recall across all instances. In repeated events for which a schema is still developing, any deviations are less likely to be noticed and more likely to have negative effects on recall of the deviation instance. Finally, across all experiments, participants memory of the first instance was better than their memory of any other instances. I discuss implications of this research for theory of adults' memory for repeated events and deviation effects in this context, and practical implications of the findings in investigative interviewing settings.

Chapter 1. Introduction

> "Three butterflies flew down. 'Grasshopper,' said the butterflies, 'you will have to move. Every afternoon at this time, we fly to this mushroom. This is the mushroom we always sit on.'
>
> Grasshopper got up. The three butterflies sat down. 'Each and every day we do the same thing at the same time. We wake up in the morning. We scratch our heads three times. Then we open and close our wings four times. We fly in a circle six times. We go to the same tree and eat the same lunch. After lunch we sit on the same sunflower, take the same nap and have the same dream. When we wake up, we come here. Always.'
>
> 'Don't you ever change anything?' asked Grasshopper. 'No, never,' said the butterflies. 'Each day is fine for us.'" (Adapted from Lobel, 1986, pp. 43-50.)

For the butterflies in Lobel's (1986) fable, each day is a mere collection of routine. Although people's daily lives certainly involve more complexity and variability, there is a lot of repetition, too. Repetition has been recognized in all aspects of life from the way people use language and communicate (P. Brown, 1999), through daily experiences (Krantz-Kent & Stewart, 2007; Renoult, Davidson, Polombo, Moscovitch, & Levine, 2012), up to the macro-level of social repetition in political analyses of everyday life (Antoniades, 2008; Havel, 1975). In some cases, repeated experience is a nuisance required by a job (e.g., scripted procedures; Gioia & Poole, 1984). People are, however, also quite repetitive in how they spend their free time (e.g., Barsalou, 1988; Czikszentmihalyi & Graef, 1980), and they develop routines as preferred ways to go about their days (health professionals have learned to make use of patient's daily routines to ensure long-term consistency in the use of medication; Lerman, 2005). An occasional relief from repetition may come with unexpected changes (hereby referred to as deviations). For the butterflies, Grasshopper created such a deviation by sitting on their favourite mushroom, which led to an exchange that would typically not happen. The work described in this thesis focused on the memory for typical as well as exceptional (deviation) instances of repeated events.

Each of us likely experienced an argument with someone who remembered shared experiences a little differently than we did. There are various reasons for misremembering experiences: the reconstructive nature of memory (Bartlett, 1932;

Nadel, Hupbach, Gomez, & Newman-Smith; 2012), influences stemming from personal goals (Conway, Singer, & Tagini, 2004), and social (Bartlett, 1932; Blank, 2009; Bluck, 2003; Howe, 2011) and cultural influences (for a review, see Saito, 2000a). In the case of repeated events, there are additional consequences of repetition that may contribute to misremembering events: interference, the development of a schema, and related forgetting (e.g., Nørby, 2015).

In casual arguments but also in high-stakes situations of investigative interviewing, sometimes it matters what happened during an instance of a repeated event (e.g., Neisser, 1981). In the last four decades, a wealth of research has been devoted to understanding the specifics of children's memory for repeated events (e.g., Brubacher, Malloy, Lamb, & Roberts, 2013; Connolly & Lindsay, 2013; Danby, Sharman, Brubacher, Powell, & Roberts, 2017; Farrar & Goodman, 1992; Fivush, 1984), largely due to the fact that, in investigative interviewing of child sexual abuse cases, children may be required to recall several instances of a repeated event, which is a very difficult task (Guadagno, Powell, & Wright, 2006; Woiwod & Connolly, 2017; Woiwod, Fitzgerald, Sheahan, Price, & Connolly, 2019). Although there are relevant investigative settings in which adults may be interviewed about a repeated event (e.g., industrial accidents, Kelloway, Stinson, & MacLean, 2004; or cases of domestic violence, sexual harassment, or stalking, Sheridan, Blaauw, & Davies, 2003; van Golde, Dilevski, Deck, Cullen, & Paterson, 2018), research involving adults has only emerged in recent years (e.g., Calado, Luke, Connolly, Landström, & Otgaar, 2020; Deck, 2019; Dilevski, Paterson, & van Golde, 2019; Dilevski, Paterson, & van Golde, 2020; Kontogianni, Rubínová, Hope, Taylor, Vrij, & Gabbert, 2020; MacLean, Coburn, Chong, & Connolly, 2018; Theunissen, Meyer, Memon, & Weinsheimer, 2017; Weinsheimer, Coburn, Chong, MacLean, & Connolly, 2017; Weinsheimer & Connolly, 2019; Willén, Granhag, Anders, Strömwall, & Fisher, 2015).

There were two sources of motivation for this work.[1] The theoretical perspective of autobiographical memory inspired questions such as: what remains in memory after

[1] It was, in fact, work on my master's thesis that kindled my interest in this area. I worked on a study which investigated the accuracy of dating of autobiographical events (Literáková; 2013; Literáková & Neusar, 2011a, 2011b; Neusar, 2012). We worked with couples, and for a period of six weeks, one of the partners completed daily diary entries about events their partners experienced. In the next phase, we interviewed the latter partners: we presented them with a selection of events from the diary and asked them to estimate when each event happened. As participants verbally described the dating process,

repeated experience, are some instances more memorable than others, and how may deviations affect memory for specific instances? The applied perspective inspired questions relevant for investigative interviewing settings: to what extent are adults able to recall specific instances of a repeated event, do adults recall particular instances more accurately, to what extent do adults remember that a deviation occurred, and if they do, is such deviation awareness associated with better memory across instances of the repeated event?[2]

In the remaining part of this introduction, I[3] present theoretical frameworks that may be useful for understanding the processes related to remembering repeated events and deviation effects along with a review of related empirical literature. Then, I present a review of methodologies used in experimental investigations of schema formation and schema and deviation effects with a focus on the variability of methods and associated strengths and limitations. The purpose of this review is to provide background for methodological decisions relevant for research presented in this thesis. Finally, I provide an overview of empirical research reported in Chapters 2, 3, and 4.

The consequences of repeated experience on remembering

> "If a phenomenon is met with … too often, and with too great a variety of contexts, although its image is retained and reproduced with correspondingly great facility, it fails to come up with any one particular setting, and the projection of it backwards to a particular past date consequently does not come about. We recognize but do not remember it—its associates form too confused a cloud." (James, 1901, p. 673.)

The process that James (1901) described reflects transformation of repeated episodic experiences into the content of semantic memory (see also Linton, 2000). As

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sometimes they provided additional details or recalled other events in the hope that such information would help them decide on the date. Because we had a greater selection of events in the diaries, I could see that sometimes participants recalled details that originated at different events, or they "merged" two events into one. These types of memory errors typically occurred at events that repeated several times throughout the period (e.g., a trip to a countryside house). Finally, Connolly and Gomes's (2013) talk on repeated events at the tenth conference of the Society for Applied Research in Memory and Cognition in Rotterdam contributed to the decision on the direction of my future research.

[2] Throughout this thesis, I try to be as consistent as possible with terms referring to single and repeated experiences. I use the term "repeated event" when I refer to a set of similar experiences, and I use "instances of a repeated event" (or just "instances") when I refer to a single experience from the repeated event. "Single event" or "novel event" refer to single or novel experiences that are not (yet) repeated.

[3] A note for the use of "I" and "we" in this thesis. As an author of this thesis, I generally use the first-person singular to communicate with the reader (this occurs mainly in the thesis introduction and discussion). I use "we" to acknowledge that research described in this thesis was group work, when I refer to "us" as a research community, or when I refer to "us" as people.

shared parts of repeated experiences become abstracted into a schema (a knowledge structure that represents how events typically happen; e.g., Ghosh & Gilboa, 2014), and interference between details of specific instances accumulates, so that differentiation between their sources of origin becomes unfeasible (Johnson, Hashtroudi, & Lindsay, 1993; Postman, 1971); one becomes less and less able to recall specific experiences.[4] In the most extreme scenario exemplified in the quote above, remembering such events would simply mean recalling the schematic knowledge (and experiences of mental time travelling and autonoetic consciousness that are typical for episodic recall would, therefore, be lost; Tulving 1972, 1985). In less extreme scenarios that are probably more common in everyday remembering (Neisser, 1988), autobiographical memory for repeated events would likely involve aspects from the whole continuum between episodic and semantic memory (Cabeza & St Jacques, 2007; Renoult, et al., 2012). Remembering an instance of a repeated event would then involve recall of the generic/schematic knowledge associated with the repeated event along with specific details (some of which would likely be misattribution errors; e.g., Lindsay, 2008, 2014).

Schema formation and schema effects

Schemata help us navigate in space (e.g., Brewer & Nakamura, 1984; Brewer & Treyens, 1981), comprehend a story (e.g., Graesser, Singer, & Trabasso, 1994; Ohtsuka & Brewer, 1992; McVee, Dunsmore, & Gavelek, 2005), or predict what is going to happen at a wedding (e.g., Nakamura, Graesser, Zimmerman, & Riha, 1985; Trabasso & Broek, 1985). When we experience a novel event, the comprehension of what is going on, as well as later reconstruction of the event during recall, is drawn from the closest existing schema (e.g., Bartlett, 1932). When we experience a novel event repeatedly, shared parts of instances are abstracted, leading to the development of a new schema[5] that facilitates further processing of such events (e.g., Abelson, 1981; Ahn, Brewer, & Mooney, 1992; Bartlett, 1932; Brewer, 2000; Brewer & Nakamura, 1984; Brewer & Treyens, 1981; Conway & Pleydell-Pearce, 2000; Fivush, 1984; Nørby, 2015; Schank, 1999; Schank & Abelson, 1975).

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[4] Havel (1975) described a similar impossibility of the existence of social memory on the macro-level if everyday life is bound in regulations and dull repetitiveness.

[5] Higher-order knowledge structures have been referred to as schemata, frames, or scripts, depending on the phenomenon they are applied to. Throughout this thesis, I use "schema" as the overarching term.

Acknowledging that such cognitive processes always build on existing knowledge, the complexity of schema development ranges from generating a new schema to adapting an old schema, depending on how familiar the experience was. For familiar events, such as novel occurrences of an otherwise familiar experience (e.g., starting a Spanish language course in a newly-open language school would be a novel but familiar event due to prior experience with English language courses), a mere adaptation of existing schemata is likely to occur (Minsky, 1974; Rumelhart, Smolensky, McClelland, & Hinton, 1986; Schank, 1999). For unfamiliar events, however, the creation of a new schema (respectively, a greater adaptation or a combination of elements from different existing schemata) would be necessary to facilitate comprehension and accurate remembering. Otherwise, in the absence of an appropriate schema, cognitive processing of an unfamiliar event would rely on existing schemata, which may result in memory distortion (Bartlett, 1932; Bergman & Roediger, 1999; Collins, 2006; Freeman, Romney, & Freeman, 1987; Neisser, 1981; Northway, 1940a; 1940b; Saito, 2000b; Wagoner & Gillespie, 2014).

Theoretical predictions

In the context of repeated events, we need to consider two perspectives that offer predictions for the recall of details of instances. Schema models predict memory performance for details based on how related they are to the schema; the source monitoring framework (Johnson, et al., 1993) and the transition theory (N. R. Brown, 2016) consider memory performance for details that vary across instances. Predictions derived from these perspectives along with empirical support are described in turn. This section is concluded with a summary of predictions relevant for research in this thesis.

Schema models and the schema-confirmation-deployment framework

Basic schema models predict that recall of schema-consistent and schema-inconsistent information should be generally better than recall of schema-unrelated information (e.g., Bartlett, 1932; Brewer, 2000; Brewer & Nakamura, 1984; Brewer & Treyens, 1981). Schema-consistent information can be inferred and schema-inconsistent information is likely to draw attention and increase processing (such effects are also widely documented in the literature; Erdfelder & Bredenkamp, 1998; Fabiani & Donchin, 1995; Greve, Cooper, Tibon, & Henson, 2019; Kelley & Nairne, 2001; Tuckey & Brewer, 2003a, 2003b; van Kesteren, Ruiter, Fernández, & Henson, 2012).

The schema-copy-plus-tag model (e.g., Nakamura, et al., 1985) additionally predicts better memory for schema-inconsistent information than schema-consistent information. The model acknowledges that schema-consistent information may be variable, which makes its instantiation prone to inference-based confusion; schema-inconsistent information, on the other hand, allows a unique schema instantiation (Nakamura, et al., 1985). Davidson (1994; see also Davidson & Jergovic, 1996; Davidson, Malmstrom, Burden, & Luo, 2000; Hudson, 1988) suggests that this effect is stronger for schema-inconsistent information that has consequences for the event (e.g., a waiter dropped glasses when delivering an order). However, better memory for schema-inconsistent relative to schema-consistent information should be expected only in relatively short-term delays; in longer delays, retrieval would rely more on generic (semantic) memory (Brainerd & Reyna, 2002; Brewer & Nakamura, 1984; Reyna & Brainerd, 1995).

Farrar and Goodman (1990; Farrar & Boyer-Pennington, 1999; Farrar & Goodman, 1992) integrated previous models into the schema-confirmation-deployment framework. This framework describes the distribution of cognitive resources during processing repeated events and related patterns of recall in two phases. The first phase (schema-confirmation) involves seeking an existing schema that could be used for processing an instance, respectively attending to similar aspects of instances of a repeated event if the schema is still developing (Farrar & Boyer-Pennington, 1999; Farrar & Goodman, 1990, 1992). In novel events for which a schema has not developed yet, recall of various types of details is expected to be similar (i.e., there is no schema that would facilitate recall of schema-consistent details;[6] Farrar & Goodman, 1990). If the schema has already been developed, schema-consistent details are processed primarily; the model, therefore, predicts better recall of schema-consistent information than recall of schema-inconsistent information in this phase (Farrar & Boyer-Pennington, 1999; Farrar & Goodman, 1990, 1992).

Only after an appropriate schema has been confirmed, cognitive resources can be moved away from schema-consistent details towards processing schema-

[6] It is important to note that in the schema-confirmation-deployment framework, schema-consistent details are fixed details (i.e., details that do not change across instances) that are part of the schema.

inconsistent and variable schema-consistent details (Farrar & Boyer-Pennington, 1999). Once the second phase (schema-deployment) is reached, the model predicts good memory for fixed schema-consistent details as well as schema-inconsistent details; variable schema-consistent details may be recalled as well, although their source may be confused with other instances (i.e., children may misattribute these details to instances in which the details did not occur; Farrar & Boyer-Pennington, 1999).

There is a wealth of research that provides support for age-related effects predicted by this model: older children develop schemata faster than younger children, which contributes to their better ability to recall details of a specific instance of a repeated event (e.g., Brubacher, Glisic, Roberts, & Powell, 2011; Connolly, Gordon, Woiwod, & Price, 2016; Farrar & Boyer-Pennington, 1999; Farrar & Goodman, 1990, 1992). There is also some support for predictions related to schema-inconsistent details in an instance of a repeated event for which a schema has already developed.

Danby, Sharman, Brubacher, and Powell (2019) recently reported that children recall more schema-consistent fixed and new details when instances of a repeated event are highly similar (and therefore allow for a faster and perhaps stronger schema development) compared to when instances are more variable. Connolly et al. (2016) found that children recalled more correct details if an instance included a deviation (schema-inconsistent information) than if it only included schema-consistent (fixed and variable) details. Specifically, in Experiments 1 and 2 reported in Connolly et al. (2016), this effect was found for a *discrete* interruption of a final magic show (i.e., the interruption had no consequences for the show). In Experiment 3, Connolly et al. added a *continuous* interruption condition (i.e., the magician became forgetful for the rest of the show) and found that in this condition, younger children (6-8 years) recalled more correct details from the preceding instances (i.e., the effect generalized but was not present in the deviation instance); the effect of the discrete interruption was not replicated and no deviation effects were found in older children (9-10 years). MacLean et al. (2018) applied an interruption with consequences in two experiments with adults and found a general positive effect of the deviation on recall across all instances in Experiment 1. In Experiment 2 in MacLean et al., the deviation effect was present only in the deviation instance (however, the deviation manipulation was confounded with post-event information manipulation). Finally, some studies that applied other types of deviations (e.g., a new activity or a change in the main protagonist) found no deviation effects (Farrar & Goodman, 1992; Kontogianni, et al., 2020).

These mixed findings may indicate that some deviations are more noticeable and therefore more likely to produce a positive deviation effect (although such noticeability may be a complex issue and may depend on the stimuli used in a study). This, however, remains an empirical question because researchers have not systematically measured whether participants remember that a deviation occurred. In the next part, I turn to addressing the question of what makes a detail more likely to be correctly attributed to its source in the context of repeated events.

The source monitoring framework

Although some details of instances of a repeated event may be fixed (e.g., a language lesson always starts and finishes with the same routine greeting), most specific details vary. There is variation in content (e.g., a text that is used for a comprehension exercise) and context (e.g., weather, clothes, mood, the presence and interactions with others). Because this variation occurs within an otherwise schematic and predictable repeated event, the high number of attributes that are shared across instances contributes to interference and potential source confusion of details across instances (Johnson, et al., 1993; Lindsay, 2008, 2013; Lindsay & Johnson, 2000). This is a common finding in repeated event studies: when children are asked to recall details of a specific instance of a repeated event, they typically report details from that instance along with details that originated at other instances (such misattribution errors are referred to as internal intrusions; Woiwod, et al., 2019).

According to the source monitoring framework, accurate source attribution of details should be more likely if they possess unique characteristics that link them to the instance (Johnson, et al., 1993; Lindsay, 2008, 2013). There is indication that deviation details may possess such characteristics that, as a result, reduce misattribution errors in a deviation instance (although these effects tend to be small and therefore, are not consistent across experiments; Connolly, et al., 2016; MacLean, et al., 2018).

There are also other reasons why details from specific instances may be more memorable and have stronger links to their source. Specifically, each instance has its unique serial position within the repeated event. The transition theory (N. R. Brown, 2016) suggests that boundary instances (the first and the final instances) may possess unique qualities as they mark the beginning and the ending of a repeated event.[7] In addition, repeated experience may cause involuntary reminding of previous instances (Hintzman, 2011), which would lead to increased rehearsal of the first instance and associated details. Finally, instances differ in the amount of interference they receive from their neighbours: the first instance is free from any proactive interference, and the final instance is free from any retroactive interference (e.g., Postman, 1971). Such resulting primacy and recency effects have been documented in the literature as patterns of higher correct recall and fewer misattribution errors in the first and the final instances relative to the middle instances, although the recency effect seems to be weaker and decreases with delay (Connolly, et al., 2016; Kontogianni, et al., 2020; MacLean, et al., 2018; Powell & Thomson, 1997; see also Dilevski, et al., 2019).

Taken together, accurate source attribution of variable details of instances of a repeated event may be difficult, unless there are unique attributes that provide links between the details and their source instance. Deviation details and details of the first and the final instances may possess such unique attributes.

Predictions for recall of details of instances of a repeated event

Let me conclude with a brief integration of predictions outlined in the previous sections. For repeated events for which a schema has already developed, recall of fixed schema-consistent details should be facilitated by the schema (e.g., Farrar & Goodman, 1990; Brewer & Nakamura, 1984). Variable schema-consistent details may be easily confused across instances (e.g., Woiwod, et al., 2019), although unique characteristics of the first and the final instances should protect them from such confusion and, in turn, result in primacy and recency effects (e.g., Connolly, et al., 2016; Powell & Thomson, 1997). Schema-inconsistent information should be well remembered, at least in shorter delays (e.g., Davidson, 1994; Brewer & Nakamura, 1984). Such deviations may have a positive effect on recall and source memory for details of the deviation instance, and this effect may generalize to other instances in the repeated event (Connolly, et al., 2016; MacLean, et al., 2018). Sometimes, however, deviations have no effects on recall (e.g., Kontogianni, et al., 2020). It is possible that deviation effects depend on how noticeable the deviation is. Danby et al. (2019) suggest that deviations may be recalled

[7] I acknowledge that I use a very minimalist application of transition theory in this context.

better if instances from the repeated event are highly similar (i.e., deviations stand out more than if instances are more variable). Currently, however, we know little about how noticeable different types of deviations are in the context of repeated events.[8]

Before I outline empirical research presented in this thesis, let me provide a brief review of methodologies used in research examining schema formation and schema(-deviation) effects. The purpose of this review is to provide background for some methodological decisions and to identify gaps in the literature that inspired some of the investigations I pursued in my research.

Review of methods

In experimental settings, schema formation and schema effects have been studied with various materials such as visual patterns (Posner & Keele, 1968), paired sets of stimuli (Brod, Lindenberger, Werkle-Bergner, & Shing, 2015; Greve, et al., 2019; van Kesteren, Beul, et al., 2013; van Kesteren, Rijpkema, Ruiter, & Fernández, 2013), play sessions (e.g., Farrar & Boyer-Pennington, 1999), magic shows (e.g., Connolly, et al., 2016), or tasting sessions (MacLean, et al., 2018). The methodological differences between studies employing relatively simple and relatively complex materials are considered in turn.

Studies using simple stimuli

The methodology in these studies is based on a single-session repeated presentation of stimuli combined with testing and feedback (e.g., Greve, et al., 2019) or direct instructions for memorizing (e.g., van Kesteren, Beul, et al., 2013; van Kesteren, Rijpkema, et al., 2013) that facilitate schema acquisition. Memory performance in a critical trial (i.e., instance) is typically measured using recognition or cued recall tasks. This methodology enables researchers to study the differences in memory between details with various relations to the newly developed schema: (i)

[8] Can we try and draw predictions for whether the butterflies and Grasshopper would remember their meeting? It is quite possible that the answer would be different for each party. For the butterflies, meeting Grasshopper was, at first, an interruptive episode, which eventually turned into an enjoyable chat (in fact, it was so enjoyable that the butterflies asked Grasshopper to meet them in the same place at the same time the following day, which Grasshopper politely declined as he intended to continue his journey towards new adventures; see Lobel, 1986). Within the butterflies routine, the meeting clearly stood out and created a potential for a strong episodic memory—it was a deviation within a highly schematic instance (see Danby, et al., 2019). For Grasshopper, however, meeting the butterflies was just one of (strange and perhaps unfamiliar) encounters he experienced during the day. Just based on the variability of Grasshopper's experiences, the likelihood that he would remember this meeting is small and would rather depend on other (perhaps subjective) characteristics associated with the meeting (e.g., Thompson, 1985; Wagenaar, 1984).

details that are congruent or consistent (e.g., recognizing one chair paired with two sunflowers as an old item), (ii) details that are incongruent or inconsistent (e.g., recognizing three chairs paired with two sunflowers as a new item), and (iii) details that are unrelated or irrelevant because the schema has not been established (e.g., a variable pairing of apples and a teddy-bears; Greve, et al., 2019). However, because of the focus on schema effects (and the use of repeated presentation only for the purpose of schema establishment), these studies do not investigate phenomena that are relevant in the context of repeated events. Specifically, we cannot learn about memory for details that are schema-consistent but variable across instances (the most common type of details in repeated events), compare memory for specific instances, or test whether the presence of schema-inconsistent (i.e., deviation) details affects memory for the deviation instance and other instances.

Studies using complex stimuli

In studies that use more complex stimuli, participants are typically directly involved in some kind of (inter)action (e.g., playing a game; Brubacher, et al., 2013; or tasting vegetables; MacLean, et al., 2018). Individual instances are presented in a single session or with intervals between instances (for an examination of the spacing effect, see Price, Connolly, & Gordon, 2006). Participants are first interviewed about their experiences after a delay (i.e., there is no testing or rehearsal after each instance) using measures of cued or free recall (i.e., measures that are used in applied settings). Memory tests in these studies then focus on a variety of effects. For example, where effects stemming from repeated experience are of interest, researchers compare recall of one instance of a repeated event with recall of a single event (i.e., where no repeated experience was involved; for a meta-analysis, see Woiwod, et al., 2019). Where differences between various types of details are of interest, researchers compare recall of fixed details that are part of the schema (e.g., always wearing the same badge), variable schema-consistent details (e.g., completing a different puzzle each time), and schema-unrelated or new details (e.g., refreshing with paper fans during one instance; e.g., Danby, et al., 2019). Where differences between instances of a repeated event are of interest, researchers compare recall of the first, the final, and the middle instances (e.g., Powell & Thomson, 1997). Finally, where effects of deviations are of interest, researchers compare recall of an instance that did and did not include a deviation (e.g., Connolly, et al., 2016; MacLean, et al., 2018).

The majority of studies using the repeated-event paradigm typically measured recall of one instance, which was either selected by the researcher (i.e., the target instance; e.g., Connolly & Price, 2006; Price & Connolly, 2004) or nominated by the participant (e.g., Danby, et al., 2019). Although some researchers measured recall of more than one instance (e.g., Powell & Thomson, 1997; Danby, Brubacher, Sharman, Powell, & Roberts, 2017), a systematically measured of recall of all instances of the repeated event was reported only in two papers (Connolly, et al., 2016; MacLean, et al., 2018). Next, studies that examine deviation effects typically implement deviations of *content* (e.g., instance disruptions, changes of protagonists, changes of rooms, or new activities; Connolly, et al., 2016; MacLean, et al., 2018; Brubacher, et al., 2011; Kontogianni, et al., 2020). One study used a combination of a deviation of content and *temporal order* (i.e., changing the order of activities; Farrar & Goodman, 1990, 1992), but there is no study that would systematically investigate the effect of order deviation in the context of memory for a repeated event. Finally, repeated event studies typically use relatively familiar stimuli, which (although they are novel) likely lead to a fast adaptation or new combination of existing schemata (see Fivush, 1984; although the strength of the schema may depend on similarity across the instances; Danby, et al., 2019). Therefore, we still know little about the memory for repeated events that might require a development of a more complex schema, as would likely happen in repeated events that are less familiar.[9]

Thesis overview

In three empirical chapters and appendices, this thesis presents five experimental studies before it concludes with a general discussion. An overarching theme of the studies is the investigation of schema and deviation effects on recall of details of instances of a repeated event. The common methodology of all studies involved participants viewing or experiencing four instances of a repeated event and then recalling details of each instance. We systematically examined effects of two types of deviations that were derived from ecological properties of real-life events: content and temporal order. Most deviations applied in previous research involved a change of

[9] One might argue that the developmental investigation of memory for repeated events does address this question. Although there may be reasons to believe that the process of schema formation for familiar repeated events in very young age is parallel to schema formation for unfamiliar repeated events in adulthood, we do not yet have empirical data that would support this comparison.

what happened (i.e., a content deviation); deviations of *order* have not been examined before, although they commonly occur. In all studies, the deviation manipulation(s) were introduced in the fourth and final instance in a crossed factorial design, such that each study had four conditions: a typical content and typical order condition, a deviation content and typical order condition, a typical content and deviation order condition, and a deviation content and deviation order condition.

In addition to examining effects of the deviations on recall of the deviation instance and the whole set of instances, we measured participants' awareness of the deviation(s) (i.e., we asked them if they remembered any differences across the instances), and we examined whether such deviation awareness was associated with recall. Finally, we operationalized measures of recall organization (in the final study reported in Chapter 4, recall organization was integrated into a measure of schematic recall). These measures were intended to reflect schema formation and help us understand the mechanisms of any deviation effects.

Across the experiments, we gradually increased the complexity of stimuli from categorized word-lists (two experiments reported in Chapter 2 and one experiment reported in Appendix B) through unfamiliar stories (Chapter 3) to self-experienced interactive events (Chapter 4). These differences in stimuli had implications for how we applied deviations and defined measures of memory performance in each study. A brief summary of these and other specifications of the experiments is provided next.

Experiments 1, 2, and 3

Chapter 2 (published as Rubínová, Blank, Ost, & Fitzgerald, 2020) presents Experiments 1 and 2 in which repeated events were operationalized as categorized word-lists. Each of the four word-lists represented an instance of an overall "word-list event" and consisted of words from three word-categories. The content deviation was applied as a change of the final word-category in the final list (e.g., animals were presented instead of fruit); the order deviation was applied as a change in the temporal order of words from the first two word-categories in the final list (e.g., instead of clothes-kitchen items-fruit, the final list contained words in a changed order: kitchen items-clothes-fruit). We operationalized two measures of recall organization. Clustering reflected organization according to content (i.e., word-categories), and sequencing reflected organization according to temporal order of the word-categories.

The word-lists in these experiments were presented in a single session. Following procedures used in research where schemata are established within the experiment (e.g., Greve, et al., 2019; van Kesteren, Beul, et al., 2013; van Kesteren, Rijpkema, et al., 2013) the list-learning procedure included recall of each word-list shortly after presentation. The purpose of this immediate recall was to facilitate schema formation, and it additionally served as a measure of learning. After completing Experiments 1 and 2, we decided to examine potential effects of elimination of this immediate recall after each list on deviation effects in Experiment 3. As this experiment explored a question that departed from the main line of research in this thesis and included only observational comparisons between the experiments (i.e., it was not an explicit test of the manipulation), it is reported in Appendix B.

Experiment 4

Chapter 3 (published as Rubínová, Blank, Koppel, & Ost, in press) presents an experiment that, in addition to deviation effects, examined a more complex schema formation for an unfamiliar repeated event. We used four variations of an unfamiliar story (i.e., a story involving a sequence of actions that participants were unlikely to have encountered before) in the same paradigm as in the word-list experiments. Participants' immediate recall of each story enabled us to track schema formation, and delayed recall enabled us to examine any deviation effects. The content deviation in this experiment was applied as a change of a short sequence of ritualistic actions performed by two main protagonists towards the end of the stories. The order deviation was applied as a change in the sequence of several groups of actions in the middle of the stories, such that the beginning and the ending, as well as the overall outcome of the stories remained consistent across all stories. The richness of the data in this experiment allowed us to explore recall at several levels, from generic recall of broad themes up to recall of specific details that varied across the stories. Recall organization in this experiment was measured as the number of themes that were recalled in the correct sequence.

Experiment 5

Chapter 4 presents an experiment in which we intended to create experiences that would be as similar to real-life repeated events as possible. In parallel with child repeated event studies that use play sessions or magic shows as stimuli (e.g., Connolly, et al., 2016; Brubacher, et al., 2011), we developed a set of marketing-themed visits at which participants interacted with and evaluated various products as part of three structured activities. The content deviation applied in this experiment was a change in the goal of the final activity in the final visit; the order deviation was applied as a change in the temporal order of the first two activities in the final visit. Instances (visits) in this experiment occurred on different days within a one- or two-week interval. To be consistent with developmental studies that used a similar methodology, we first interviewed participants after a delay of one to two weeks after the final visit (i.e., we did not administer immediate recall after each visit). In this experiment, we operationalized a measure of schematic recall of the visits as recall of actions in each visit in the order they occurred (i.e., this measure combined generic recall of activities with recall organization).

Experiments in context

The experiments in this thesis were designed as a research program that would systematically examine schema and (content and order) deviation effects in adults' memory for details of instances of a repeated event. Initially, this program intended to increase the complexity of stimuli across experiments in order to increase the external validity of the findings. However, specific methodological decisions determined that experiments reported do not follow one another in a consecutive way. Rather, Experiments 1 and 2 (Chapter 2) provided a foundation for the investigation of content and order deviation effects and effects associated with deviation awareness. Experiments 3, 4, and 5 extended this investigation in three directions. Experiment 3 was a methodological exploration of possible effects that the elimination of rehearsal may have on schema formation and deviation effects (this aim diverted from the main line of research and the experiment is therefore reported in Appendix B). In Experiment 4 (Chapter 3), the use of unfamiliar stories allowed us to see if schema and deviation effects can be replicated in a repeated event that would require the formation of a complex new schema. Finally, in Experiment 5 (Chapter 4), the development of stimuli similar to autobiographical repeated events allowed us to see if effects found with simple stimuli can be replicated with the use of ecologically valid materials.

Chapter 2. Structured word-lists as a model of basic schemata: deviations from content and order in a repeated event paradigm

Published as:

Rubínová, E., Blank, H., Ost, J., & Fitzgerald, R. J. (2020). Structured word-lists as a model of basic schemata: deviations from content and order in a repeated event paradigm, *Memory*, *28*, 309-322. https://doi.org/10.1080/09658211.2020.1712421

Ethics code: SFEC 2014-010 (Appendix E).

Abstract

Repeated events are common in everyday life, but relatively neglected as a topic within memory psychology. In two samples of adults, we investigated memory for repeated, schema-establishing simple events (operationalised as structured word-lists), and the effects of deviations within those events. We focused on the effects of deviations from two core dimensions of schema: content and order. Across three successive word-list events, we established and reinforced a basic list schema by always presenting three content categories in the same order. These expectations were violated in a fourth and final word-list. We measured the effects on memory of both the violating and the schema-establishing lists in multiple recall attempts over a period of one month. We measured correct recall, misattribution errors, metacognitive awareness of list-organization and deviations, and recall organization. Across all delays and across all word-lists (not only the final one), content changes increased recall, whereas order changes decreased recall. Participants were also more aware of content changes than order changes. These disparate effects suggest that the two types of schema-deviations may have qualitatively different effects on memory for specific instances of a repeated generic event. Cognitive processes underlying memory for typical and exceptional instances of repeated events are discussed.

Introduction

When people experience a series of instances with similar content and structure, an abstracted representation of those experiences—a schema—is created in their memory (Abelson, 1981; Ahn, et al., 1992; Ghosh & Gilboa, 2013; Nørby, 2015; Renoult, et al., 2012; Schank, 1999; Schank & Abelson, 1975). Previous studies into schema development and schema effects have used various types of simple materials from visual patterns (e.g., Posner & Keele, 1968), multimodal object-like sets of stimuli (van Kesteren, Rijpkema, et al., 2013), paired associates (van Kesteren, Beul, et al., 2013), and familiar and unfamiliar stories or videos (Bartlett, 1932; Davidson, et al., 2000; Tuckey & Brewer, 2003a, 2003b). These studies, however, typically used repeated presentation of materials to establish the schema and then investigate its effects without examining participants' memory of specific instances, or they used a single presentation of an event for which a culturally transmitted schema already existed (e.g., dining at a restaurant, a university lecture, or a bank robbery).

We tested memory for a series of structured word-lists to explore two core dimensions of an event schema: content and temporal order (Minsky, 1974; Schank & Abelson, 1975). Both dimensions should influence how the event is recalled, but previous research has primarily focused on effects of content. Our focus on effects of order is a novel contribution to the literature. While the order of actions is usually fixed across repeated instances, there are many events that allow some variability in the order while retaining their overall schema. Take, for example, a magic show, which consists of a set of (arbitrarily) ordered tricks. A visitor to several shows of the same magician would likely establish a schema of the show in terms of which tricks occur in what order. If the magician performed a new trick, an event with a content deviation would be created; if the magician changed the order of tricks, an event with an order deviation would be created. Staff meetings, personal routines, or medication regimens embedded in daily tasks are other examples of repeated events for which schematic order becomes established yet permits variability. The use of repeated word-lists with consistencies in structure enabled us to systematically examine how deviations in order and content affect recall of all instances within the series of word-list events.

Schema (deviation) effects on memory

Once a schema for a set of instances is developed, it has top-down consequences for how details of those instances are recalled (e.g., Brewer & Nakamura, 1984). Even when specific details are not available in memory, schematic (i.e., gist) information is often readily available (Brainerd & Reyna, 2002; Brewer & Nakamura, 1984; Farrar & Boyer-Pennington, 1999; Farrar & Goodman, 1992). An interesting question then is how this schema information interacts with memory for the individual instances. If a series of events contains highly similar instances, specific details are likely to be confused (Farrar & Boyer-Pennington, 1999; Brubacher, et al., 2011), or absorbed into the schema (e.g., Bartlett, 1932; Brewer & Treyens, 1981), resulting in limited ability to distinguish between the source of origin (Johnson, et al., 1993). If one instance deviates from the schema, however, the event can become distinctive and the details can become more memorable (e.g., Brewer, 2000; Connolly, et al., 2016; Nakamura, et al., 1985; Schank, 1999; Schank & Abelson, 1975).

A distinctive instance can have implications for the recall of typical instances as well. Schemata automatically adapt to new experiences (Bartlett, 1932; Collins, 2006; Schank, 1999; Wagoner, 2013), for example, by incorporating variability that comes with a deviation instance. A deviation can serve as a contrasting experience and promote rehearsal of details of other instances through retroactive facilitation (Higham, Blank, & Luna, 2017; Hintzman, 2011; Putnam, Sungkhasettee, & Roediger, 2017). In such case, updating of the schema would be paired with conscious processing of the deviation and active strengthening of content and source memory for details of all instances. Therefore, an effect of a deviation that was present in a single instance would be expected to spread on the whole set of events—a process we refer to as generalization. What we do not know, however, is whether we should expect recall-enhancing effects for all types of deviations, and what is the role of deviation awareness in this process.

A content deviation can be well remembered, and these effects have typically been studied using pre-existing schemata. For example, using a story describing dining at a restaurant, Davidson, et al. (2000) found the highest recall and most stable long-term retention (up to one week) for script-interruptive actions (e.g., when a waiter dropped wine glasses; see also Davidson, 1994; Davidson & Jergovic, 1996). Tuckey and Brewer (2003a) showed participants a video of a bank robbery and found that schema-consistent and -inconsistent details (e.g., the robber escaping on a bus) were recalled equally well across two delayed, free-recall interviews.

Repeated-event research has similarly focused on the effects of content deviations. Farrar and Boyer-Pennington (1999, Experiment 1) found that children often correctly recalled a completely new activity (such as having a snack or playing with Play-Doh), but confused minor changes in activities that occurred in preceding instances (for a similar finding, see Brubacher, et al., 2011; Farrar & Goodman, 1992). Further, Connolly et al. (child participants, 2016) and MacLean et al. (adult participants, 2018) assessed recall at the level of whole instances and found that participants who experienced an interruption that had consequences for the way one of the events occurred (a content deviation) recalled more details from all instances in the series than participants who did not experience such interruption. To our knowledge, the only order deviation in repeated-event study was confounded with a content deviation and the effects could not be disentangled (Farrar & Goodman, 1992).

What do these sets of findings tell us overall? Deviations in an event's content, such as an unexpected interruption, may be well remembered and may strengthen source memory. Further, if the content deviation occurs in one instance of a repeated event, the effect of that deviation may improve memory for other instances in the series. What these sets of findings do not tell us is what happens if the order deviates, and whether findings from child samples generalize to adult samples.

The current research

We conducted two experiments investigating adults' memory for structured word-lists in a repeated event paradigm (where the successive lists represent successive instances of a repeated event). The events in our experiments comprised a set of four categorized word-lists. We expected that participants would, over the first three lists, establish and reinforce a schema for the lists' content and order (e.g., animal words followed by clothing words followed by fruit words). In the fourth and final word-list, one of three types of deviations was introduced: (i) a new word-category (content deviation), (ii) a change in the sequence of presentation of the typical word-categories (order deviation), or (iii) both types of deviations combined; this was complemented by (iv) a baseline condition (no deviation). We measured recall of all four lists, which allowed us to examine whether final lists that deviated from the schema were recalled differently than final lists that adhered to the schema, and also to examine whether effects of the deviation list generalized to recall of the schema-establishing lists. This is of particular interest in the context of newly established schemata, as deviations may undermine the emerging schema, with consequences for the recall of the typical instances as well. Moreover, the use of the method of repeated reproduction (Bartlett, 1932; i.e. having the same participants recall at multiple occasions) enabled us to track any changes over multiple delay intervals (see also Tuckey & Brewer, 2003a).

Conceivably, the content deviation might enhance correct recall of the final word-list by tagging the instance as being distinctive (Nakamura, et al., 1985; Shank & Abelson, 1975; see also Stangor & McMillan, 1992). The list facilitation effect (enhanced recall of a list that contains an item that differs from the others in size or semantically; e.g., Cimbalo, Nowak, & Stringfield, 1978; Fabiani & Donchin, 1995) and release from proactive interference (Wickens, 1970) might add support to a prediction for an increase in correct recall of the list containing the deviation, at least in the short term.

For order, we would expect participants to organize their recall to match the order at presentation (Tulving, 1962). However, research on order effects is lacking and analyses involving order were exploratory. In Experiment 2, we probed potential processes involved in both content and order deviation effects, such as deviation awareness and recall organization.

Experiment 1

Method

Design

This experiment used a 2 (content: typical/changed) × 2 (order: typical/changed) × 4 (list: first/second/third/fourth) × 2 (delay: 10 min/one day) mixed design with content and order as between-subjects factors and list and delay as within-subjects factors. Dependent variables were correct recall (proportion of words recalled from the correct source-list) and internal intrusions (proportion of words recalled with incorrect source). We did not analyse external intrusions (typically same-category words that were not included in any of the lists) because they were very rare (1.1% of recalled words across all participants, lists, and tests, and such low number precluded statistical analyses).

Participants

Ninety-six participants (51 women and 45 men aged between 18 and 40 years, mostly university students from Prague and Brno, Czech Republic) took part in the experiment and completed both sessions. Participants were randomly allocated to one of four conditions (each *n* = 24) by selecting an envelope with condition assignment. All participants reported that they had normal or corrected-to-normal vision and confirmed that they had (i) followed instructions (at the end of Session 1) and (ii) completed the whole experiment honestly (at the end of Session 2).

Materials

Word-lists were created by ordering words from three categories (i.e., a total of nine words in each list). The relative position of each category was counterbalanced (ABC – BCD – CDA – DAB). The number of words from each category in each list was systematically varied: the category that was presented first comprised four words, the second comprised three words, and the last comprised two words. An example of four lists used in four conditions can be found in Table 1.

Table 1
Example of word-lists in baseline and deviation conditions

			List 4			
List 1	List 2	List 3	Both typical	Content deviation	Order deviation	Both deviation
Fridge	Kettle	Fork	Spoon	Spoon	Dolphin	Dolphin
Jug	Cooker	Jar	Mug	Mug	Goat	Goat
Grill	Sponge	Freezer	Saucepan	Saucepan	Parrot	Parrot
Sieve	Dishwasher	Funnel	Teapot	Teapot	Spoon	Spoon
Deer	Elephant	Tiger	Dolphin	Dolphin	Mug	Mug
Goose	Frog	Donkey	Goat	Goat	Saucepan	Saucepan
Penguin	Hen	Pigeon	Parrot	Parrot	Teapot	Teapot
Sweater	Trousers	Pyjamas	Purse	**Strawberry**	Purse	**Strawberry**
Shawl	Blouse	Socks	Bra	**Grapefruit**	Bra	**Grapefruit**

Note. Content deviations are in bold. Order deviations are in italics. Categories in Lists 1-3 are kitchen items, animals, and clothes. The deviation category in List 4 is fruits. English equivalents of Czech words that were used in the experiment are displayed.

The word-lists were designated as List 1, List 2, List 3, and List 4. To provide participants with a simple contextual cue (Hupbach, Hardt, Gomez, & Nadel, 2008), each list was presented on a different background colour (yellow, green, orange and blue for Lists 1 through 4, respectively). In each recall phase, the respective lists were referred to by a corresponding number and background colour.

Each participant saw four word-lists. To establish and reinforce the schema, the first three lists were presented with words from the same three categories in identical order (e.g., animals – kitchen items – fruit). Changes were introduced in the fourth word-list except for the baseline condition. In the content deviation condition, a new word-category appeared in place of the third category (e.g., animals, kitchen items, clothes). In the order deviation condition, the order of presentation of word-categories changed (e.g., kitchen items – animals – fruit). In the combined condition, both content and order changed (e.g. kitchen items – animals – clothes).

Procedure

Participants consented to take part in a multiple-session study. They were informed that they would engage in several different computer- and paper-based tasks during Session 1 and that they would be invited to complete one follow-up session via online form (no further details about the online form were provided).

Session 1. During Session 1, participants were presented four word-lists, one at a time, and instructed to pay attention to the words (presented one at a time) as they would be asked to recall them later (see Figure 1). After viewing each list twice, they completed arithmetic problems for 1 min, and then recalled as many words from the list as they could. The main reason for including this immediate recall phase was to allow rehearsal and (at least partial) consolidation, and to increase subsequent recall due to the testing effect (e.g., Roediger & Butler, 2011; Roediger & Karpicke, 2006a, 2006b). Participants were instructed not to guess. To separate the different word-lists in time, participants completed a 2-minute filler task between reproduction and presentation of the next word-list. After reproduction of List 4, participants reported their gender, age, and compliance with instructions throughout the experimental session (as a check of potential dishonest behaviour; Mazar, Amir, & Ariely, 2008). A 9-minute filler task followed in which participants could choose to complete a crossword puzzle, Sudoku, or a complicated dot connection task.[10] The experiment was programmed using OpenSesame (Mathôt, Schreij, & Theeuwes, 2012) and self-administered.

[10] An immediate check after Session 1 confirmed that each participant worked on at least one distractor task from the selection.

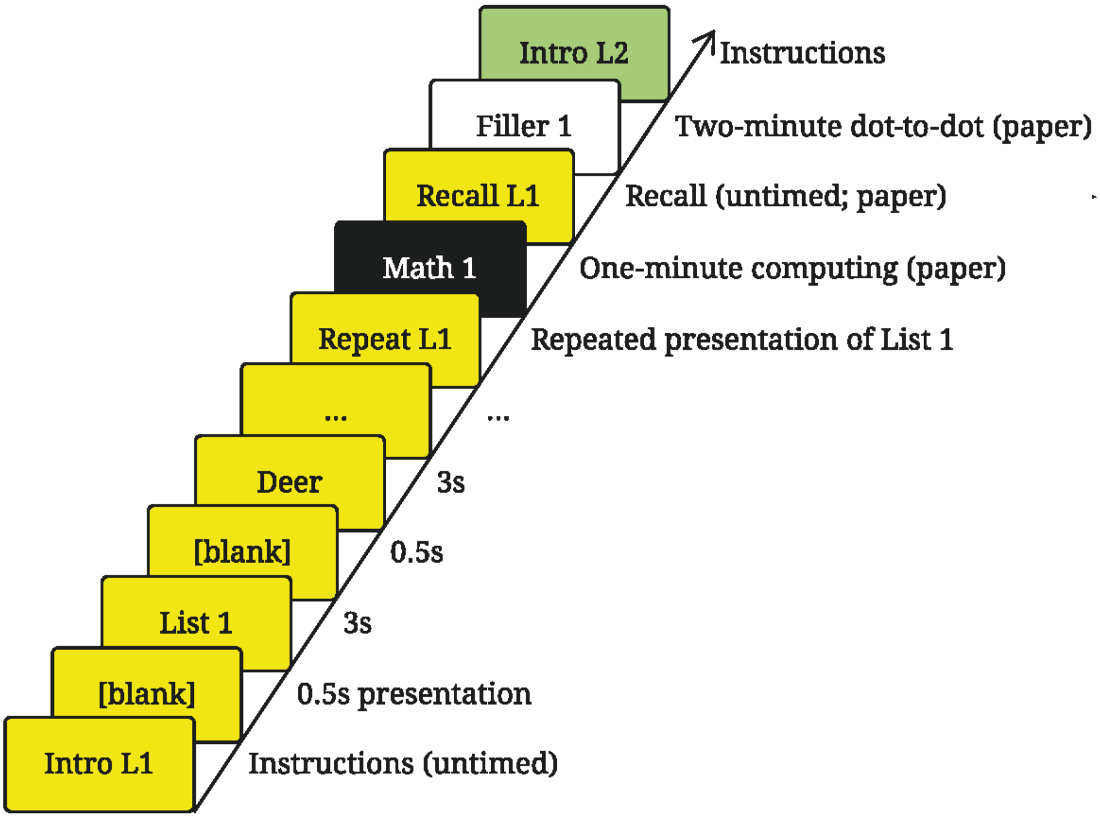

Figure 1. A flowchart of the learning phase of Session 1.

Session 1 concluded with a first delayed recall task in which participants were asked to report as many words as they could from each of the four lists without guessing. Participants completed an online answer form that comprised four pages with list-matching background colour and a corresponding list designation (they could switch between the pages).

Session 2. One day (M = 1.30, SD = 0.59 days) after Session 1, participants received an online form identical to the delayed recall task they completed in Session 1. They were asked to complete it in a quiet place without distractions.

Statistical analyses

Recall was analysed using linear mixed models (LMM) with fixed effects of delay (10 min/1 day), list (1/2/3/4), content (typical/deviation), and order (typical/deviation), and random intercepts for list nested within participants (Finch, Bolin, & Kelley, 2014). The model included two- and three-way interactions between delay, content, and order, and list, content, and order. Because we wanted to primarily examine the main effects of the deviations (in a regression context), we coded all categorical independent variables using simple contrasts. That is, for the deviations, the contrasts compared typical vs deviation content/order (similar to main effects in the context of analysis of variance); for list, we coded List 1 as the reference level, so three contrasts compared recall of List 1 to recall of List 2, 3, and 4.

We present regression coefficients along with 95% Confidence Intervals (*CI*s) to show the range of plausible values (Cumming, 2012, 2014). For main effects and contrasts, the interpretation of the regression coefficients is straightforward: *b* shows the size of the change in the recall measure for a given level of the factor. For example, *b* = -0.50 for a proportion of correctly recalled details means that participants' recall in a given condition was 50% lower than in the comparison condition. For interactions between content and order deviations, the regression coefficient indicates a difference in the effect of the content deviation between the two levels of the order deviation. Therefore, negative values of *b* indicate that the effect of the content deviation was stronger in the deviation order conditions, and positive values indicated that the effect of content deviation was stronger in the typical order conditions.

The analyses were run in R version 3.3.1 (R Core Team, 2016) using the `lme` function from the `nlme` package (Pinheiro, Bates, DebRoy, Sarkar, & R Core Team, 2017). The complete R script and the data set can be found in Online Supplemental Materials (OSM) under https://osf.io/bzvfw/.

Results

Overview

After showing that there were no substantial differences between conditions in terms of the learning of List 4, we present two main sets of results: schema (deviation) effects on correct recall and list/instance discrimination as reflected in internal intrusion errors. Although we included interactions with delay and list in all LMMs, these analyses were not pertinent to our hypotheses and are not reported here. Interested readers may reproduce the analyses and examine the effects (in brief: forgetting, and primacy and recency effects) using our data and R script provided as OSM (https://osf.io/bzvfw/).

Learning

The initial reproduction completed for each list after a 1-minute distractor task served as a measure of learning and was not included in any statistical analyses of delayed recall reported below. Neither content nor order deviations significantly affected the initial reproduction of List 4 (content: *b* = 0.01, 95% *CI* [-0.05, 0.06], *t*(92) = 0.34, *p* = .74); order: *b* = -0.04, [-0.10, 0.01], *t*(92) = 1.51, *p* = .13), suggesting that the findings in the next sections cannot be attributed to differences in initial learning of List 4.

Correct recall

Correctly recalled words were measured as the proportion of recalled words correctly attributed to the list in which they were presented. In general, the recall data showed forgetting (~12% between sessions 1 and 2) and primacy and recency effects (Figure 2). These effects were consistently present in all our further analyses but did not interact with the effects most relevant to this paper and are not discussed further.

List 4. The core schema deviation analysis yielded a significant main effect of order: when order deviated, recall of List 4 was 15% lower than when order was schema-consistent (*b* = -0.15, 95% *CI* [-0.26, -0.03], *t*(92) = 2.58, *p* = .01). The content deviation effect was not significant (*b* = 0.06, [-0.06, 0.17], *t*(92) = 0.97, *p* = .34). The interaction between the content and order deviations was not significant (*b* = 0.04, [-0.13, 0.21], *t*(92) = 0.42 *p* = .68). Descriptive statistics split by condition are reported in Table 2.

Table 2
Experiment 1: Mean proportion of correct recall and internal intrusions in all conditions across delay

	Correct recall				Internal intrusions			
	List 4							
Session	Typical	Content	Order	Both	Typical	Content	Order	Both
1	.75 (.25)	.75 (.32)	.54 (.32)	.59 (.33)	.14 (.23)	.09 (.15)	.19 (.25)	.12 (.23)
2	.51 (.27)	.52 (.32)	.32 (.27)	.49 (.33)	.18 (.22)	.15 (.22)	.20 (.26)	.10 (.23)
	All lists							
1	.58 (.31)	.62 (.35)	.48 (.29)	.55 (.32)	.16 (.21)	.15 (.23)	.21 (.22)	.14 (.21)
2	.46 (.28)	.51 (.33)	.35 (.25)	.43 (.30)	.17 (.19)	.15 (.21)	.23 (.23)	.16 (.21)

Note. Typical = typical content and order; Content = deviation content and typical order; Order = typical content and deviation order; Both = deviation content and order. Statistics display means and standard deviations.

All lists. Figure 2 shows the effect of the order deviation on recall of List 4 generalized to recall of the schema-establishing lists: correct recall across all lists was 9% lower if the fourth list included an order deviation than if the fourth list was ordered consistently with the first three (b = -0.09, 95% *CI* [-0.17, -0.002], $t(92)$ = 2.03, p = .04). The content deviation was associated with a descriptively higher recall of the same magnitude as for List 4, but the effect was not significant (b = 0.06, [-0.02, 0.15], $t(92)$ = 1.41, p = .16). There were no significant interactions either between delay and content/order deviations, or between list and content/order deviations. These results suggest that the schema-level deviation effects spread to the instances that initially generated the schema, and, in addition, that the pattern of content and order effects persisted essentially unchanged across all the recall sessions.

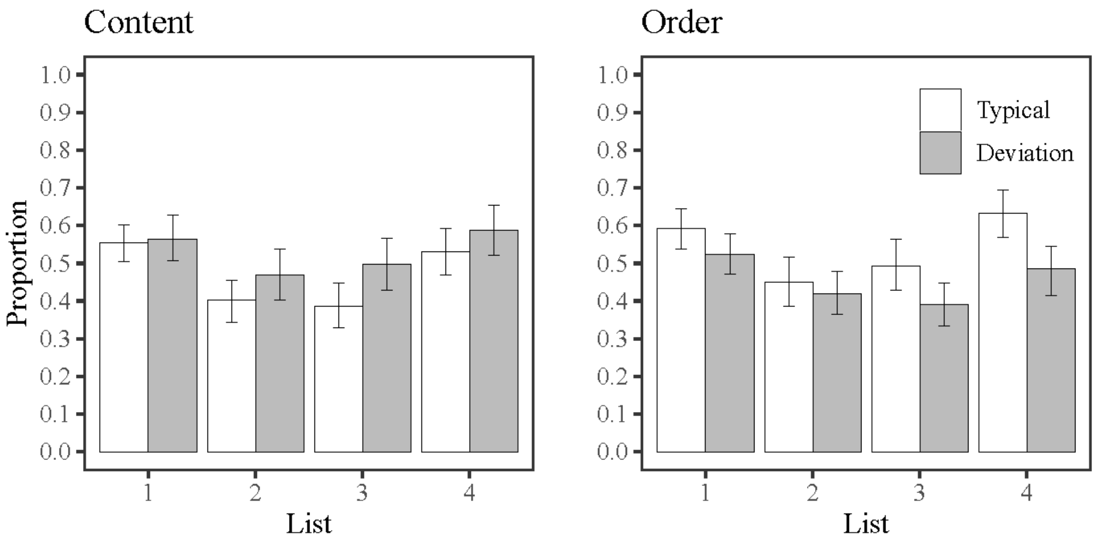

Figure 2. Proportion of correctly recalled words from all lists for content and order deviations collapsed across delay. Error bars represent 95% *CI*s of the means.

Internal intrusions

One reason why schema effects in recall might spread across instances/lists is confusion of source memory (e.g., Johnson et al, 1993)—details/words can be misattributed to other instances/lists, thereby lowering recall performance for the specific list in question. For example, if a participant correctly remembers all nine words from List 4 but attributes one of them to List 3 and another to List 2, performance for List 4 would be only 7/9 = 78% correct. In turn, List 2 and List 3 performance would be lowered as well because of the intrusions from List 4 (and possibly other lists).[11] That is, such internal intrusions would have reciprocal effects on recall performance of all involved lists, allowing the schema-deviation effects to spread from the schema-deviation list (List 4) to the schema-establishing lists (Lists 1 to 3). Our next set of analyses explored the frequency of such internal intrusions.

List 4. There were no significant effects for either deviation on the proportion of internal intrusions into List 4 (content: *b* = -0.06, 95% *CI* [-0.15, 0.02], *t*(92) = 1.47, *p* = .14; order: *b* = 0.01, [-0.07, 0.10], *t*(92) = 0.32, *p* = .75; see also Table 2).

All lists. Figure 3 displays the patterns of internal intrusions across all lists. Essentially, these figures are mirror-images of the correct recall patterns displayed in Figure 2: conditions associated with better recall were less likely to elicit internal intrusions, and vice versa. However, neither of the effects was significant (content: *b* = -0.04, 95% *CI* [-0.09, 0.01], *t*(92) = 1.74, *p* = .08; order: *b* = 0.03, [-0.02, 0.08], *t*(92) = 1.18, *p* = .24).

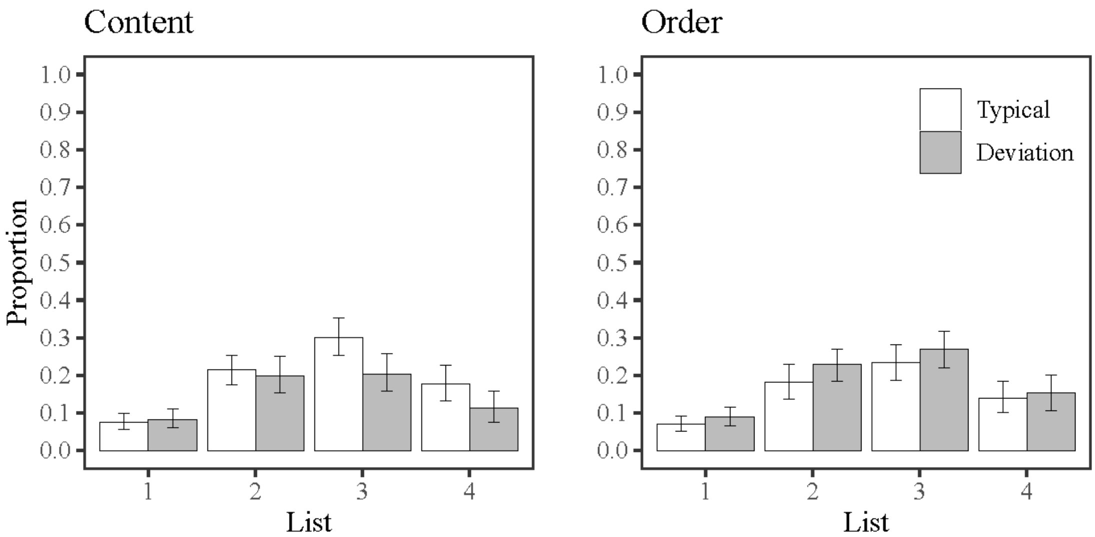

Figure 3. Proportion of internal intrusions in all lists for content and order deviations collapsed across delay. Error bars represent 95% *CI*s of the means.

[11] Theoretically, participants could report and correctly attribute all words to a specific list and then recall some additional words from other lists, in which case internal intrusions would not have consequences on correct recall. However, reporting of more than 9 words per list was rare.

Discussion

The principal finding of this experiment was the disruptive effect of the order deviation on correct recall. This decrease was more substantial for the list that was the immediate target of the order manipulation (List 4, -15%), but a similar effect was also found when we considered all the lists in the series (-9%). Change of content was associated with higher correct recall, but the effect was not significant and weak.[12] Interestingly, despite statistical weakness of the individual effects, the pattern was consistent across all lists, which suggests a schema-level effects that spread to all the instances that initially generated the schema.

Experiment 2

Experiment 2 was a close replication of Experiment 1 with a few methodological refinements that are described in the relevant sections below.

Method

Design

Delay was extended up to four levels (10 min/one day/one week/one month). In addition to correct recall and internal intrusions, we measured awareness of deviation (aware/not aware), clustering (number of category clusters in recall), and sequencing (recall sequenced/not sequenced according to order at presentation).

Participants

Eighty participants (54 women and 26 men aged between 18 and 45 years, mostly university students from Prague and Brno, Czech Republic) took part in the experiment and completed all the sessions. All participants reported normal or corrected-to-normal vision and confirmed that they had (i) followed the instructions (at the end of Session 1) and (ii) completed the whole experiment honestly (at the end of Session 4). Participants were randomly allocated to one of four conditions (each n = 20).

[12] One reason for the weakness of the effect of the content deviation may be the size of the category that was changed (two words). Therefore, we decided to drop the category-size distinction in the replication Experiment 2.

Materials

We dropped the variability in category size, such that all lists were represented by three exemplars from each category. In order to enhance the context of the word-lists, we used a cover story introducing the word-lists as selections of words that an international student called Vincent (who is keen to learn Czech) studied on four consecutive days. Each word list was therefore designated by a day of the week (e.g., words that Vincent learned on Monday), and preceded by a photograph of Vincent (different for each list). List designation, background colour, and photograph were used as cues in each recall phase.

Procedure

The procedure for Session 1 was the same as in Experiment 1, and all further sessions comprised of online forms (mean delay of Session 2: M = 1.16, SD = 0.40 days, Session 3: M = 7.41, SD = 0.79 days, Session 4: M = 29.00, SD = 1.74 days). To obtain information about deviation awareness, in the final online form (Session 4), we included questions concerning the organization of the lists and any changes participants might have noticed and remembered. If participants remembered and could correctly articulate the deviation, their responses were coded as aware of the deviation; incorrect descriptions were coded as not aware of the deviation. Awareness of deviation was coded by two independent raters who showed 90% agreement (disagreement was resolved by discussion, and agreed scores were used for analyses). For exploratory purposes, we also asked participants to rate their motivation, perceived task difficulty, and to report any encoding and recall strategies they might have adopted.[13] After all participants responded, we sent them a debriefing sheet.

Statistical analyses

Recall was analysed using linear mixed models (LMM) with fixed effects of delay (1/2/3/4, treated as a continuous variable and centred), list (1/2/3/4), content (typical/changed), and order (typical/changed), and random intercepts for list nested

[13] Participants perceived the whole experiment as moderately difficult (from 1 = easy to 7 = difficult; M = 4.48, SD = 1.25) and had moderate motivation to complete each of the recall sessions (scale from 1 = not at all motivated to 7 = highly motivated; M = 4.81, SD = 1.45). These data were not used for any statistical analyses.

within participants and random slopes for session across list nested within participants[14] (Finch, et al., 2014). The model included two- and three-way interactions between session, content, and order, and list, content, and order. All categorical independent variables were coded using simple contrasts. The complete R script with the data set can be found in OSM (https://osf.io/bzvfw).

Results

Overview

We present five sets of results. After reporting the learning check and recall and internal intrusion analyses, we present results that focus on participants' metacognitive awareness of the schema (i.e., their perceived organization of the word-lists and any deviations therefrom). Finally, we present analyses of the schema deviation effects on recall organization. For awareness and organization analyses, we only examined effects across all lists. We report additional analyses that were not central to the focus of this paper in Appendix A.

Learning

As in Experiment 1, there were no significant effects of deviations on initial reproduction of List 4 (content: $b = 0.02$, 95% *CI* [-0.02, 0.06], $t(76) = 1.06$, $p = .29$; order: $b = 0.00$, [-0.04, 0.04], $t(76) = 0.00$, $p = 1.00$).

Correct recall

List 4. The deviation analysis indicated a significant main effect of content: when content deviated, List 4 recall was 12% higher than when content was schema-consistent ($b = 0.12$, 95% *CI* [0.01, 0.23], $t(76) = 2.22$, $p = .03$). When order deviated, List 4 recall was 11% lower than when order was schema-consistent; however, this effect was not significant ($b = -0.11$, [-0.20, 0.02], $t(76) = 1.98$, $p = .05$). Descriptive statistics split by condition are reported in Table 3.

The content deviation effect was stronger than in Experiment 1, where the effect was in the same direction but not significant. In principle, this effect is in line with our general reasoning in the introduction (i.e., better memory for deviations from expectations; e.g., Stangor & McMillan, 1992). In order to more specifically determine

[14] We arrived at this model by comparing three models: (i) fixed-effects-only, (ii) random intercepts for *list* nested within participants, and (iii) random slopes for delay across list nested within participants and found that the last one showed the best fit.

the effect of the deviation words, though, we conducted an analysis that excluded words from the final category in List 4 (i.e., words that were changed in the content deviation conditions and parallel words in the typical content conditions) and calculated List 4 accuracy as a percentage of the remaining 6 words. This analysis revealed that the content deviation effect was largely driven by the deviation words and was no longer significant when these words were excluded (b = 0.04, 95% CI [-0.9, 0.16], t(76) = 0.58, p = .56). By contrast, the order effect remained very much unchanged (b = -0.11, [-0.24, 0.01], t(76) = 1.81, p = .07).

Table 3
Experiment 2: Mean proportion of correct recall and internal intrusions

	Correct recall				Internal intrusions			
	List 4							
Session	Typical	Content	Order	Both	Typical	Content	Order	Both
1	.79 (.22)	.78 (.22)	.72 (.22)	.79 (.24)	.10 (.12)	.12 (.15)	.12 (.13)	.10 (.11)
2	.66 (.29)	.70 (.27)	.44 (.29)	.64 (.31)	.07 (.12)	.06 (.10)	.18 (.18)	.12 (.13)
3	.53 (.31)	.60 (.32)	.32 (.22)	.57 (.28)	.11 (.15)	.06 (.08)	.18 (.20)	.09 (.12)
4	.37 (.28)	.56 (.32)	.26 (.21)	.41 (.31)	.10 (.12)	.04 (.09)	.11 (.13)	.07 (.12)
	All lists							
1	.63 (.31)	.68 (.29)	.53 (.30)	.67 (.32)	.12 (.17)	.12 (.17)	.12 (.16)	.13 (.20)
2	.55 (.33)	.63 (.32)	.38 (.31)	.58 (.33)	.11 (.18)	.11 (.17)	.20 (.21)	.15 (.17)
3	.48 (.35)	.54 (.34)	.28 (.26)	.53 (.31)	.12 (.19)	.12 (.18)	.23 (.23)	.13 (.15)
4	.32 (.28)	.47 (.33)	.25 (.23)	.32 (.30)	.14 (.17)	.10 (.14)	.14 (.17)	.15 (.19)

Note. Typical = typical content and order; Content = deviation content and typical order; Order = typical content and deviation order; Both = deviation content and order. Statistics display means and standard deviations.

All lists. Both deviation effects generalized to the schema-establishing lists (Figure 4). Across lists, the content deviation was associated with 12% higher recall (b = 0.12, 95% CI [0.02, 0.23], t(76) = 2.30, p = .03), whereas the order deviation was associated with 9% lower recall (b = -0.09, [-0.20, 0.02], t(76) = 1.70, p = .09). Although the effect of the order deviation was nonsignificant, the trend is consistent with the effect observed in Experiment 1. The interaction between the content and order deviations was not significant (b = 0.08, [-0.14, 0.29], t(76) = 0.73, p = .47).

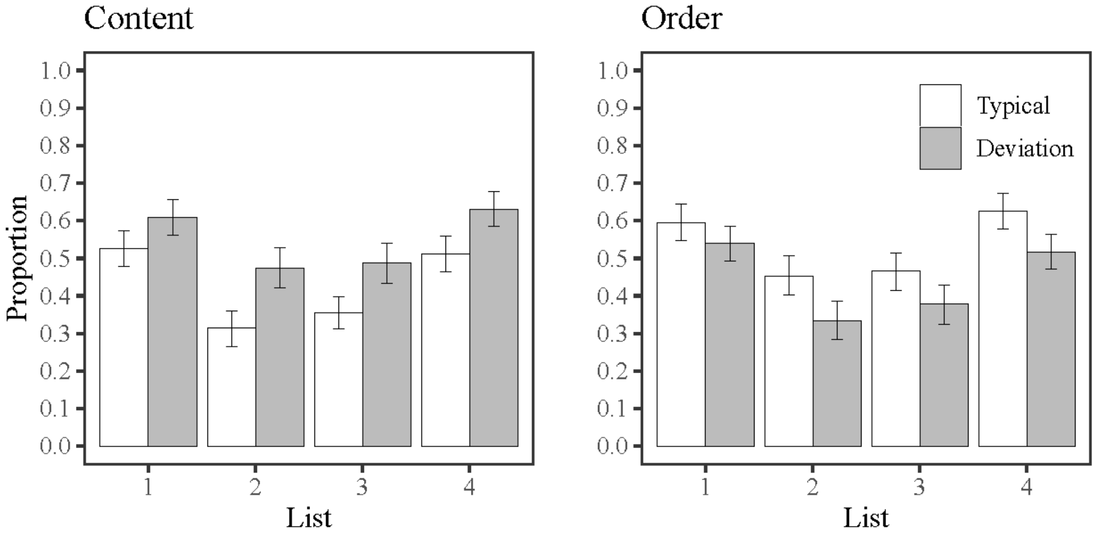

Figure 4. Proportion of correctly recalled words from all lists for content and order deviations collapsed across delay. Error bars represent 95% *CI*s of the means.

A parallel analysis excluding words from the final category in List 4 revealed a consistent pattern of results, but the effect of the content deviation was weaker (~10% increase) and no longer significant (b = 0.10, 95% *CI* [-0.01, 0.21], $t(76)$ = 1.85, p = .07). Result for the effect of order was similar to the previous analysis (b = -0.09, [-0.20, 0.02], $t(76)$ = 1.68, p = .10).

Internal intrusions

List 4. As in Experiment 1, the patterns of internal intrusions were inversely related to correct recall: the content deviation was associated with a 4% lower proportion of internal intrusions (b = -0.04, 95% *CI* [-0.08, 0.005], $t(76)$ = 1.73, p = .09) and the order deviation was associated with a 4% higher proportion of internal intrusions (b = 0.04, [-0.003, 0.08], $t(76)$ = 1.87, p = .07), although neither effect was significant.

All lists. Figure 5 shows consistent patterns of deviation effects on internal intrusions across all lists in the series. Although neither effect was significant (content: b = -0.02, 95% *CI* [-0.06, 0.02], $t(76)$ = 1.09, p = .28; order: b = 0.04, [-0.002, 0.08], $t(76)$ = 1.87, p = .07), the trend indicated by the order deviation is in line with the idea that, to some degree, schema-deviation effects can spread across instances through source confusion: the decrease in correct recall is mirrored by an increase in internal intrusions.

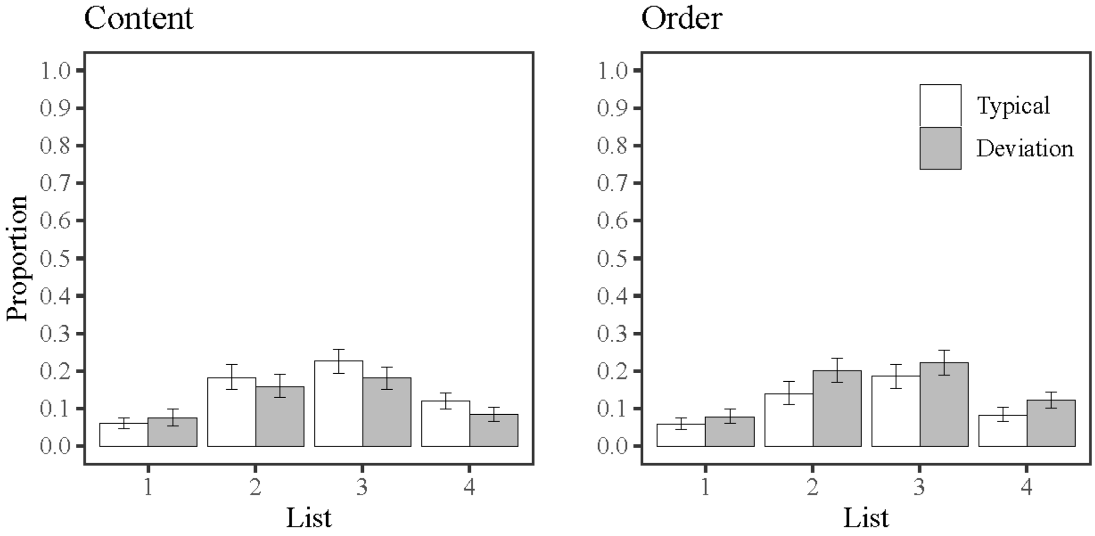

Figure 5. Proportion of internal intrusions in all lists for content and order deviations collapsed across delay. Error bars represent 95% *CI*s of the means.

Awareness of schema (disruption)

The next set of analyses focused on metacognitive measures probing (1) awareness of the schema for the word-lists, (2) awareness of changes in the schema-deviation list (List 4), and (3) the relationship between awareness and recall.

At the end of the final recall session, participants were first asked to describe how the word-lists were organized. Most participants (87.5%) correctly described the initial organization in terms of both content and order (e.g., *"If I remember correctly, first, there were clothes, then fruit, and then items related to cooking and eating were presented at the end"*). Second, 95% of participants in the baseline condition (typical content and typical order*;* n = 20) correctly reported that there was no change to the organization of the word-lists. Of the participants in the condition with changed content but typical order (n = 20), 15 (75%) correctly described this change (e.g., "*On the last day animal words appeared instead of fruit words"*). In contrast, only 40% in the condition with changed order but typical content (n = 20) indicated that some change of order occurred, even though the descriptions were usually incorrect (e.g., *"Yes, on Thursday the order of the triplets was swapped: instead of fruit – kitchen items – animals, triplets of fruit – animals – kitchen items were presented"*; note that the actual change in this case was kitchen – fruit – animals) or vague (e.g., *"Yes, one day the categories were swapped"*). Finally, in the condition with both changed content and order (n = 20), only 25% described both changes (e.g., *"Yes, Thursday was different.*

First, there were kitchen items, then fruit, and instead of animals, there were pieces of clothes"). However, looking at the changes in the combined condition separately, we found that 15 participants (75%) correctly described the change of content and seven described some change of order (35%). Overall, content deviations were reported twice as often (by 75%, or 30 out of 40; content and both conditions) than order deviations (37.5%, or 15 out of 40; order and both conditions), $\chi^2(1, N = 80) = 9.96$, $p = .002$; $OR = 5.00$, 95% *CI* [1.91, 13.06]).[15]

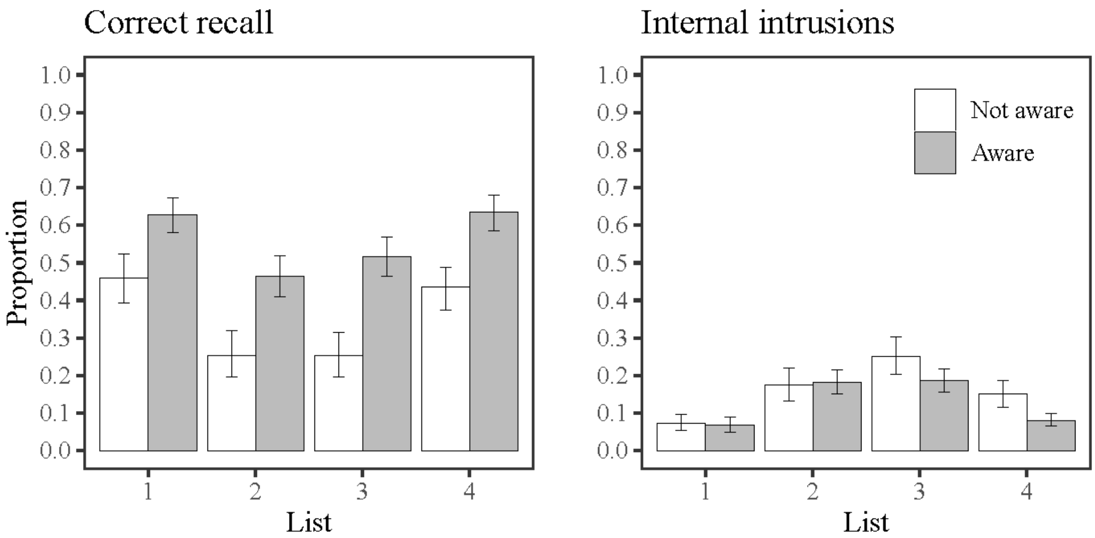

Figure 6. Proportion of correctly recalled words and internal intrusions from all lists for participants who were/were not aware of any deviation collapsed across delay. Error bars represent 95% *CI*s of the means.

We further explored the potential association between content and/or order deviation awareness (in the respective conditions that included a deviation) and correct recall, using an LMM that included awareness in the fixed part of the model along with delay, list, and all interactions, and allowed random slopes for delay and random intercepts for lists nested within participants. The results revealed that participants who mentioned a deviation recalled, on average, 21% more words than participants who did not report a deviation ($b = 0.21$, 95% *CI* [0.08, 0.34], $t(58) = 3.30$, $p = .002$; Figure 6).

[15] Looking back at our metacognitive measure of the awareness of the original organization of the word-lists, we realized that participants often mentioned that the word-lists comprised words from specific categories, but less often explicitly mentioned the order. They usually expressed the order as an example, and if the example matched the original order of the categories in the lists, we scored it as correct. Using the correct sequence, however, does not necessarily represent *awareness* of the order as the organizing principle.

We found no significant association between the correct articulation of the deviation and internal intrusions (b = -0.03 [-0.08, 0.02], $t(58) = 1.32$, $p = .19$).

In summary, the metacognitive measures indicate that almost all participants correctly described the schema underlying the word-lists, suggesting that three instances provided enough experience to capture both dimensions of organization—content as well as temporal order. However, distinct differences occurred in reporting the change in the last instance: most participants described the change of content, whereas considerably fewer participants described the change of order. The results regarding relatively low awareness of the order deviation are particularly interesting, because that change was associated with a decrease in correct recall.

Clustering and sequencing in recall

In the final set of analyses, we looked at whether the two defining features of the schema—content and order—were reflected in recall (i.e., whether participants' recall was organized into categories and sequenced according to the presentation order), and whether the respective manipulations of the schema affected this organization. In order to quantify the appearance of the different parts of schema in recall, we defined measures of clustering and sequencing.[16] Clustering was coded as follows: each consecutive occurrence of two or more words from the same category—provided that there were no more occurrences of words from this category later in the list—was awarded one point for cluster (e.g., AAABCC would be awarded two points, one for cluster A and one for cluster C; AABCCA would be coded as just one point for cluster C). The coding did not consider the size of the clusters to limit confounding the measure with correct recall. Three points for clustering was the maximum available per list (there were three categories in each list).

On average, participants recalled 1.8 out of the three categories in clusters (b_0 = 1.81, 95% *CI* [1.64, 1.97]). We found a positive main effect of content: across all lists and intervals of delay, participants in the content deviation conditions clustered

[16] Another way of looking at recall organization is to ask participants whether they had used any recall strategies (because these are usually based on some level of organization). Encoding and recall strategies of our participants typically matched—they tried to make use of the encoding strategy during recall. Approximately 70% of participants reported a recall strategy during encoding that was associated with images or stories that aimed to create connections among the words from a list. Two thirds of these participants mentioned selecting words from categories, which indicates that clustering might appear in recall. However, for the purposes of data analysis, we decided to measure categorisation (clustering) and sequencing based on recall protocols.

their recall more than participants in the typical content conditions (*b* = 0.39, [0.06, 0.72], *t*(76) = 2.33, *p* = .02; Figure 7). The effect of the order deviation was in the expected direction (opposite to the content deviation), but weaker and nonsignificant (*b* = -0.28 [-0.60, 0.05], *t*(76) = 1.64, *p* = .10).

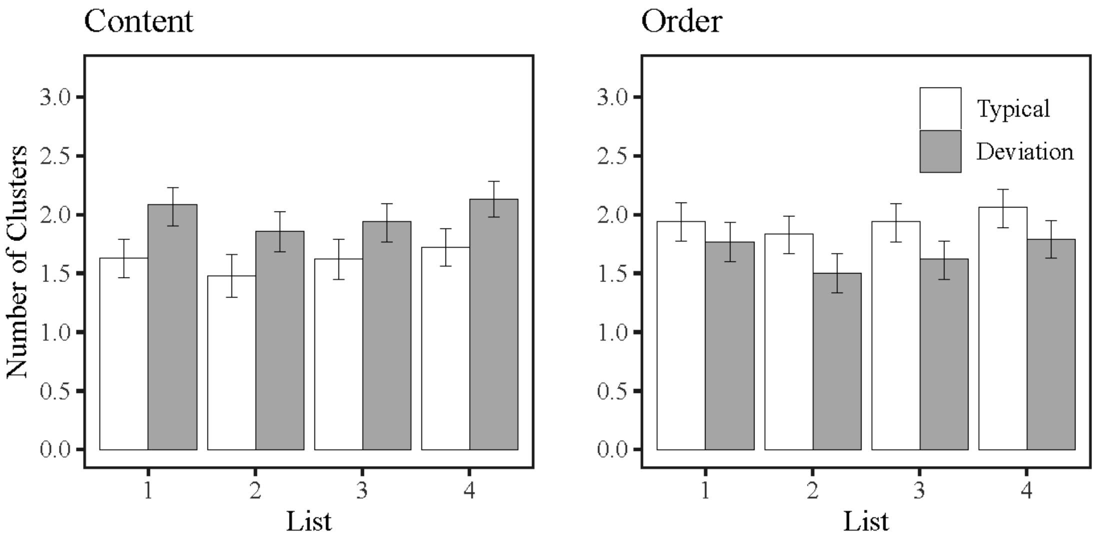

Figure 7. Number of clusters in all lists for content and order deviations (collapsed across delay). Error bars represent 95% *CI*s of the means.

To code sequencing in recall, we first converted words into categories (again, irrespective of size). Sequenced recall was then coded if the order of categories corresponded to the order at presentation (including deviation order), provided that there were no more occurrences of these categories later in the list (e.g., ABC, AB, BC, and AC would all be coded as sequenced recall; ABCB, BCAB, or any other combination would be coded as not sequenced recall). Each list was coded as sequenced (1) or not sequenced (0). Please note that both clustering and sequencing were intended to capture recall organization and therefore were coded from complete recall protocols that included internal and external intrusions, that is, both types of intrusions were treated the same way as correctly recalled words.

For sequencing, a multilevel generalized linear model (specifically, a multilevel logistic regression) was built using the `glmmPQL` function from the `MASS` package (Venables & Ripley, 2002) with the same fixed and random factors as in the previous LMMs. We found that participants in the changed order conditions were less likely to sequence their recall according to order at presentation (*b* = -1.64, *SE* = 0.45,

$t(76) = 3.67$, $p < .001$, $OR = 0.19$; Figure 8). The effect in the changed content conditions was in the opposite direction, but much weaker and nonsignificant ($b = 0.72$, $SE = 0.45$, $t(76) = 1.62$, $p = .11$, $OR = 2.06$).

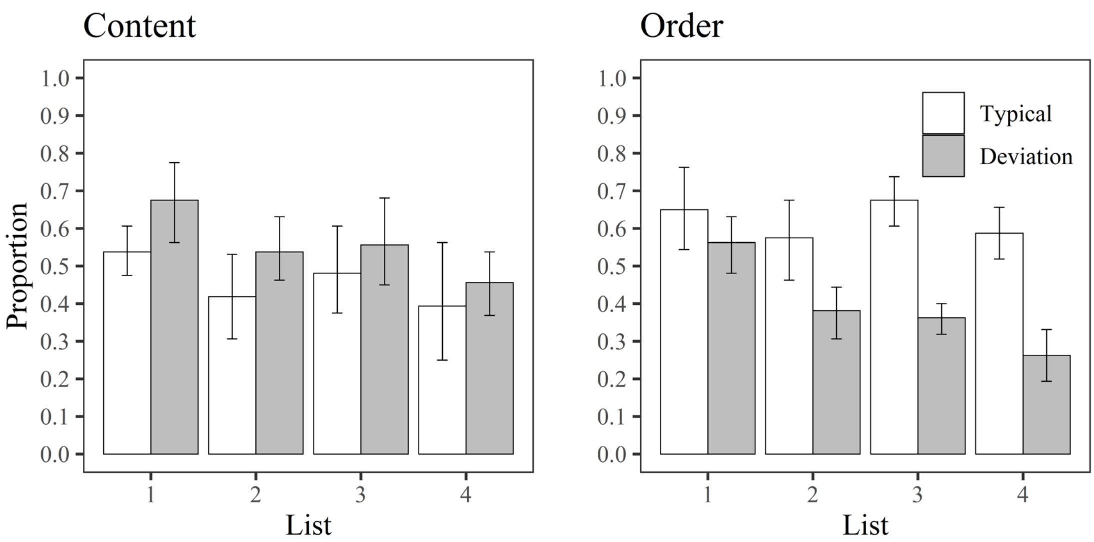

Figure 8. Proportion of correct sequencing in all lists for content and order deviations (collapsed across delay). Error bars represent 95% *CI*s of the means.

In summary, the results of the recall organization measures show that both parts of the schema (content as well as order) manifested in recall organization and were affected by the schema deviations. The key findings here are: (1) the effects of the deviations that originated in the schema-deviation list (List 4) spread into the schema-building lists (Lists 1 to 3), and (2) the two types of deviations had different effects on recall organization. There was a clear schema-disruption effect when the order was changed (participants less often sequenced their recall). Changing the content, on the other hand, did not result in schema disruption; instead, this change had the effect of strengthening the schema of the word-lists in terms of content (i.e., the deviation led participants to recall words according to categories).

General Discussion

Repeated events are ubiquitous in daily life and represent a substantial proportion of our autobiographical memory, yet investigations into how adults remember specific instances from a set of repeated events are surprisingly rare (MacLean, et al., 2018; Willén, et al., 2015). We investigated memory for instances of repeated word-lists with a focus on the effects of two types of schema deviations on recall across several delay intervals.

Our findings indicate that introducing new content into the last instance of a repeated word-list event enhanced correct recall across all instances, although this effect was at least partly driven by particularly good recall for the deviation words. Metacognitive measures of list organization revealed that nearly all participants were able to correctly describe the initial organization of the word-lists, but awareness of the deviations seemed to depend on the nature of the deviation. The content change was mentioned by twice as many participants as the order change, and an exploratory analysis revealed that awareness of either type of deviation was associated with higher correct recall. The content deviation also increased organization of recall into category clusters.

Connolly et al. (2016) and MacLean et al. (2018) found a similar generalized recall-enhancing effect of a deviation from content presented in an instance from a series of repeated events (magic shows with children and tasting sessions with adults, respectively). These general effects of a content deviation cannot be fully explained by the list facilitation effect (Cimbalo, et al., 1978; Fabiani & Donchin, 1995) or release from proactive interference (Wickens, 1970), as these would be (i) limited to the target instance, and (ii) most pronounced in the short-term (i.e., in our study, the effects would interact with delay).

Changing the order of presentation of the word-categories in the last instance manifested in a memory-disrupting pattern of effects across all four measures we investigated. In correct recall, the effect was consistent with the disruption of recall organization reported by Postman (1971). Again, this disruption was not limited to the schema-deviation (final) instance but manifested in the schema-building instances as well, suggesting a schema-level effect. There was a lack of awareness for the change of order, which may suggest poor cognitive monitoring at the time of presentation, retrieval, or both (e.g., Koriat & Goldsmith, 1996; Koriat, Goldsmith, & Pansky, 2000). Although we cannot tell from their reports, participants might have not noticed that such a change occurred, they might have noticed and considered it unworthy of note, or they might have noticed it, but forgotten about it by the time we asked. Looking at participants' recall organization offers another perspective on this issue. Recall protocols provide direct evidence of the impact of the schema-deviations on participants' use of the organizing principle that defined the schema of the word-lists, in this case, sequencing category-recall according to presentation order: across all lists, the order deviation disrupted sequencing.

Remembering instances of a repeated event

Although we have used simple stimuli, the way participants recalled our structured word-lists may have implications for how adults remember typical and exceptional instances of a repeated event. We propose a schema interpretation. Developing a schema for a repeated event starts with establishing a representation of the first event. Then, subsequent events play an important role: a consecutive similar event leads to recall of the previous instance (e.g., Schank, 1999) and abstraction of similarities of content and "rules" of procedure. A general representation of the events including information about what typical instances include and how they proceed—a schema—is created. This schema is then confirmed and reinforced by subsequent similar instances (Farrar & Boyer-Pennington, 1999; Farrar & Goodman, 1992).

Each event is then represented in memory as a schema instantiation—a general level of information about all events associated with specific details belonging to separate instances (Brewer, 2000; Brewer & Nakamura, 1984; Brewer & Treyens, 1981). This applies to the first instance as well, because we assume that during the process of schema development, the representation of the first instance is recoded as it becomes a part of the series of repeated events. During memory reconstruction, the schema provides general guidance and, if details are still accessible, the task is to differentiate between instances. Whether details are attributed to the correct instance depends on the strength of the source memory (e.g., Johnson, et al., 1993).

Instances including deviations may impact either on the schema, on source memory, or both. If a further instance includes a deviation that marks the instance as a special case (Schank, 1999; Schank & Abelson, 1975), as would likely happen with a content deviation, there should be associated metacognitive awareness of this deviation. The schema might then be modified to include the content deviation as a variation within the set of instances. Acknowledging an instance with a content deviation necessarily leads to contrasting the deviation with the content of the typical instances and would likely involve a rehearsal of previous instances (Connolly, et al., 2016 explained their effects similarly). This process would have consequences for schema-based recall as well as for recall of details of instances from the repeated event: we should observe an increase in correct recall and a corresponding decrease in source-monitoring errors across instances.

The consequences for remembering instances of a repeated event seem to be different if an instance deviates from the preceding ones in terms of the sequential organization (i.e., what typically happens proceeds in a different way), and the disparity between the effects of the two types of schema-deviations suggest that they might be qualitatively different. Content is prominent in people's perception and seems to be crucial for discriminating and highlighting typical and exceptional cases. Therefore, a content deviation reinforces this aspect of the schema and subsequently aids recall. In contrast, temporal order is less often explicitly noticed (possibly forgotten, or not considered worthy of mention) and is therefore vulnerable to being undermined by deviations. At the same time, order was important for guiding recall—as shown in the positive correlations between the measure of schematic organization (sequencing) and correct recall (see Appendix A). We speculate that an order deviation compromises the sequential aspect of the schema that is implicit yet necessary for effective memory reconstruction, resulting in a negative effect on recall. Low awareness of such deviation means that the instance would not stand out, which has immediate consequences for source monitoring. Overall, the order deviation results in disrupting schema-guided recall organization, decreasing the number of correctly recalled details, and increasing source misattribution errors.

Limitations and future directions

This research had two main limitations. First, the materials that we used were relatively simple, and second, all the instances were presented during one session. Autobiographical repeated events are highly complex and never occur in isolation from personal or social contexts, which both influence remembering (e.g., Blank, 2009; Conway, 2005). Instances may be separated by days, weeks or even months, and this temporal as well as contextual separation may help limit confusion among instances (i.e., internal intrusions). Despite these differences, we believe that our choice of methodology was appropriate for our aim in this study—the focus on basic memory processes in an area that has not been studied before required high experimental control. Also, as to the deviation from content, a similar recall-enhancing effect that we described was found in a study that assessed memory for autobiographical events in children (Connolly, et al., 2016). Nevertheless, we believe that replicating the effects in future research, using more realistic materials (e.g., with stories or experienced events), is necessary to establish the ecological validity of our findings.

We point to two further directions for future research. First, metacognitive monitoring in repeated events deserves further investigation, given the differences we found in participants' reports of the deviations from content and order. Based on our data, we cannot be certain whether participants did not report the change of order because of poor cognitive monitoring or because they thought that it was not worth mentioning—resolving this might help to better understand the qualitative differences between content and order as parts of the schema. Secondly, we changed the content and order of the last instance only. It remains to be seen whether similar effects would be found if the deviation was presented in a different position within the series of repeated events. In other words, would there be a similar recall-enhancing effect of an instance including a content deviation if this instance was the first or second event? And would there be a similar recall-disrupting effect of an instance including an order deviation if this instance was followed by further schematic—perhaps correcting—instances?

Studying memory for repeated events will further our understanding of autobiographical memory generally. Many of our everyday experiences are in fact variations of the same schematic event; however, certain events are more memorable than others. Our study, using a basic word-list analogue of real-life repeated events, took the first step in investigating the diverse effects that changes in content and/or temporal order have on remembering instances of repeated events in adults. Future research with more complex and realistic materials will help determine whether our findings extend to applied contexts.

Acknowledgements

The authors would like to thank Marek Vranka, Pavel Humpolíček, Stanislav Ježek, Otto Eibl, and Roman Chytilek for providing laboratory space and equipment; Hana Řádová, Veronika Horníčková, Dominika Štěchová, Adam Olejár, Lucie Stroupková, and Edita Fedorková for assisting during data collection; and Jonathan Koppel for providing valuable feedback on an early draft of the manuscript.

Chapter 3. Schema and deviation effects in remembering repeated unfamiliar stories

Published as:

Rubínová, E., Blank, H., Koppel, J., & Ost, J. (in press). Schema and deviation effects in remembering repeated unfamiliar stories, *British Journal of Psychology*. https://doi.org/10.1111/bjop.12449

Ethics code: SFEC 2014-010 (Appendix E).

Abstract

In today's globalised world, we frequently encounter unfamiliar events that we may have difficulty comprehending—and in turn remembering—due to a lack of appropriate schemata. This research investigated schema effects in a situation where participants established a complex new schema for an unfamiliar type of story through exposure to four variations. We found that immediate recall increased across subsequent stories and that distortions occurred less frequently—participants built on the emerging schema and gradually established representations of parts of the story that were initially transformed. In recall with delays increasing up to one month, quantitative measures indicated forgetting while distortions increased. The second focus of this research was on content and order deviation effects on recall. The content deviation, in contrast with previous repeated-event research, was not remembered well and was associated with lower recall; the order deviation had a similar (but expected) effect. We discuss discrepancies between results of this study and previous literature, which had focused on schemata for familiar events, in relation to stages of schema development: it seems that in unfamiliar repeated events, a complex new schema is in the early stages of formation, where the lack of attentional resources limits active processing of deviations.

Introduction

> "Two men from Edulac went fishing" (participant's first recall, Bartlett, 1932, p. 66).

Bartlett (1932) demonstrated that parts of an unfamiliar story may become distorted in the process of remembering (see also Bergman & Roediger, 1999; Roediger, Bergman, & Meade, 2000). In one of Bartlett's (1932) experiments, participants were presented with an adapted version of a North American folktale *The War of the Ghosts*, which started with the following line: "One night two young men from Egulac went down to the river to hunt seals…". Bartlett's participants were then asked to reproduce the story repeatedly with increasing delay. In their reproductions, participants often left out or transformed parts that were most disjoint to their pre-existing knowledge (i.e., parts they had difficulty comprehending; Bartlett, 1932; see also Beals, 1998; Billig, 1990; Edwards & Middleton, 1987). The initial quote shows an example—the participant changed "hunt seals" into the more familiar "fishing" and "Egulac" into "Edulac". In today's globalised world, we frequently encounter unfamiliar events that we may have difficulty comprehending due to lack of appropriate schemata. Watching a game of cricket may serve as an example—a first-timer would probably not understand much of what is going on, and if asked to recall the event later, they would likely need to borrow terms they know from different sports, misinterpret certain actions, and overall not remember very much. What if, however, one had a chance to become familiar with the event through exposure to several examples—would we still observe distortions?

Repeated experience leads, through the process of abstracting shared parts of events, to the emergence of a schema, a generic cognitive structure that consists of information about content and temporal order of events (i.e., a script), layout of spaces, and rules or associations between objects (Abelson, 1981; Ahn, et al., 1992; Brewer & Treyens, 1981; Ghosh & Gilboa, 2014; Nørby, 2015; Posner & Keele, 1968; Renoult, et al., 2012; Rumelhart, et al., 1986; Schank, 1999; Schank & Abelson, 1975; van Kesteren, Rijpkema, et al., 2013). Repeated event research from experimental as well as naturalistic settings has investigated various consequences that newly established schemata have on the ability to recall specific details of events that were similar to each other. In general, schemata facilitate memory for what typically happened but are less helpful when the task is to recall details that varied across instances (e.g., Farrar &

Goodman, 1992; Fivush, 1984; Freeman, et al., 1987; Neisser, 1981; McNichol, Shute, & Tucker, 1999; Woiwod, et al., 2019). There is an exception to the latter principle, however, when changes in details are so unexpected as to be perceived as outright deviations, in which case these deviations are remembered well (Brubacher, et al., 2011; Connolly, et al., 2016; Greve, et al., 2019; MacLean, et al., 2018).

Previous studies, however, typically investigated familiar repeated events such as play activities, tasting sessions, school days, and group meetings and discussions, so new schemata were rather adaptations of old schemata than complex new structures.[17] Given that people experience repeated unfamiliar events in many different contexts (when they travel to countries with a different culture, play a new board game, learn to drive, or switch to a new operation system) and sometimes need to recall details of these events for investigative purposes (e.g., in cases of industrial accidents; Kelloway, et al., 2004), we need to gain better understanding of how memory for such events develops and how such events are remembered. In the present research, we used a set of variations of an unfamiliar story in a repeated event paradigm, and we followed participants' recall using a method of repeated reproduction with increasing delay. This unique combination of methodologies enabled us to examine (i) schema formation for unfamiliar material and effects associated with cultural schemata as well as (ii) phenomena specific for repeated events, such as accuracy of recall instances and effects of deviations.

Conventionalization and unfamiliar stimuli

"When cultural material is introduced into a group from the outside it suffers change until it eventually either disappears or reaches a new stable form" (Bartlett, 1932, p. 268). This process of conventionalization illustrates socio-cultural influences on remembering that involve assimilation of unfamiliar forms to familiar ones often through processes of rationalization, simplification, and social constructiveness that

[17] We would like to note that schema establishment for any new human experience, even in the case of unfamiliar events, never occurs from a "blank slate", because there are always aspects that are familiar (e.g., subjects, objects, and various actions in isolation). In this research, we focus on events that are unfamiliar as a whole and that lead to complex schema adaptations.

may result in distortion (Bartlett, 1932; Collins, 2006; Northway, 1940a; 1940b; Saito, 2000b).[18]

Transformations (or distortions) as a result of constructive processes apparent in recall have been documented in studies using familiar and unfamiliar material with the method of repeated reproduction. Bergman and Roediger (1999) and Wagoner and Gillespie (2014) replicated Bartlett's experiment using the *War of the Ghosts* story and showed that memory distortions tend to be maintained across repeated tests while accurate recall decreases due to forgetting. Wheeler and Roediger (1992) reported similar results with the use of familiar materials.[19] Bartlett (1932) further mentioned that some distortions only occurred at longer retrieval attempts. This would likely happen in cases where a new schema is still separating from existing schemata. The relative persistence of distortion in delayed recall documented by Bergman and Roediger (1999) and Wagoner and Gillespie (2014) exemplify the conservative nature of stabilised schemata (Collins, 2006; Ost & Costall, 2002).

Remembering repeated events

In everyday life, people form routines, follow procedures, and create preferred ways for completing complex tasks.[20] From this perspective, our lives largely seem a collection of repeated events (N. R. Brown, 2016). Two decades of research into children's memory for repeated events and emerging literature on adults' memory for repeated events suggest that people tend to remember the content and structure of how things typically happen (Woiwod, et al., 2019). When asked about details of a specific event, participants are often confused about when details occurred, may provide inconsistent reports across repeated interviews, and in turn may seem unreliable

[18] Cole and Cole (2000) elaborated on Bartlett's notion of conventionalization and suggested that it entails transformative as well as generative processes (i.e., that conventionalization involves processes of assimilation of details as well as accommodation of schemata). In this study, we use a narrower interpretation of conventionalization as a transformative and constructive process that is driven by an established schema (e.g., transformation of "hunting seals" into "fishing" or recall of "totem" that never actually occurred in War of the Ghosts; Bartlett, 1932).

[19] Gauld and Stephenson (1967) studied conditions that may limit distortions in recall and suggested that strict recall instructions and an opportunity to identify errors in participants' own reproductions have such an effect.

[20] Imagine a personalized Monday morning routine of an academic. She enters the office at 9.00, engages in a brief discussion about the weekend. She then pours coffee that one of her colleagues (who arrives to the office earlier and has a different routine) had made. Until 9.30, she answers emails while sipping coffee. After that, she starts revising slides for an upcoming lecture that she gives at 10.00.

(Connolly & Price, 2013; Freeman, et al., 1987; Price, Connolly, & Gordon, 2016; Neisser, 1981; Weinsheimer, et al., 2017; Woiwod & Connolly, 2017).

The source monitoring framework (Johnson, et al., 1993; Lindsay, 2008; Lindsay, 2014; Lindsay & Johnson, 2000) is a useful approach that may help us understand why difficulties in remembering details of an instance of a repeated event occur. The source monitoring framework is based on the assumption that memory processes at all stages involve multiple systems that work in parallel (Johnson, et al., 1993; see also McClelland & Rumelhart, 1985; Rumelhart, et al., 1986). During retrieval of a specific detail, these systems give rise to a host of surface-level and generic characteristics that aid the process of attributing the detail to a specific source (Lindsay, 2008). In repeated events, many of these characteristics overlap, which may lead to erroneous attributions (i.e., confusions of details across instances), unless a detail is associated with unique characteristics. There are two examples of such stronger bounds between details and their source in repeated events: (i) primacy (and sometimes also recency) effects, when recall of the first (and sometimes the last) instance of a repeated event is higher and contains fewer confusions than recall of other instances; and (ii) deviation effects, when an instance that was different from others is recalled better than non-deviation instances (Connolly, et al., 2016; Greve, et al., 2019; MacLean, et al., 2018; Roberts, Brubacher, Drohan-Jennings, Glisic, Powell, & Friedman, 2015; Rubínová, et al., 2020). The latter effect is typically associated with a content deviation such as a new activity or an interruption present in one instance, and is consistent with literature examining deviation effects presented in a scripted text, where recall of script-interruptive, bizarre, or vivid irrelevant details was found to be similar or better than recall of script-typical details (Davidson, 1994; Davidson, et al., 2000).

An event may also deviate in terms of temporal structure (i.e., when an established arbitrary order of actions changes in one instance), and such deviation seems to have a disruptive effect on recall and source memory of all instances, possibly due to compromising the schematic basis that otherwise aids comprehension (Ohtsuka & Brewer, 1992) and recall (Rubínová, et al., 2020).[21] Recent research also suggested

[21] In the context of an order deviation in a (single) story, J. M. Mandler and Johnson (1977) suggested that an apparent order deviation may lead to better recall of the story in the short term. "However, the longer the delay between telling and recall, the more recall will come to approximate an ideal schema instead of the actual story heard" (p. 132).

that being aware (i.e., remembering) that a deviation occurred may be key to understanding deviation effects: a deviation of content was associated with high deviation awareness and better recall, while a deviation of order was associated with low deviation awareness and poorer recall (Rubínová, et al., 2020).

The current study

In the present study, we combined methodologies to answer questions pertaining (i) to schema formation and persistence of memory distortion in repeated unfamiliar events, and (ii) to the generalisability of effects found in the repeated-event literature that are based on familiar stimuli. We presented participants with four versions of an unfamiliar story and asked them to recall each story shortly after its presentation (immediate recall), and then again four more times with delays increasing from 10 minutes to one month (delayed recall). In addition, we investigated effects of content and order deviations on delayed recall of unfamiliar stories. For different subsets of participants, in the fourth and final story, we introduced a content deviation (a change in behaviour of the characters),[22] an order deviation (a change in the sequence of actions), or both content and order deviations.

With regards to schema formation, we hypothesised that participants' initial recall of the first story—after their first experience with the unfamiliar material—would be lower than their initial recall of the subsequent stories due to gradual establishment of the schema (e.g., Fivush, 1984; Schank, 1999). Relatedly, we expected that as participants became more familiar with the material and built a new schema, the number of distortions in initial recall would decrease between the first and subsequent stories (i.e., initial distortions would be corrected). We planned exploratory analyses of distortions in delayed recall to see if occurrence of distortions was stable across time or would show increasing tendencies (Bartlett, 1932).

In delayed recall, based on previous repeated-event research using familiar materials, we should expect (i) primacy and recency effects—higher recall and better source monitoring in Story 1 and 4 than in the middle stories (MacLean, et al., 2018; Rubínová, et al., 2020), (ii) positive effects of the content deviation on recall (e.g.,

[22] The content deviation we used would correspond to a vivid schema-inconsistent detail that did not have consequences for the story in terminology used by researchers examining deviation details in scripted stories (e.g., Davidson, 1994), as it involved a change of the ritualistic behaviour enacted by the couple at the end of the story.

Price, et al., 2016), and (iii) negative effects of the order deviation on recall (Rubínová, et al., 2020). Whether these effects are generalisable to repeated unfamiliar events remains to be established and therefore we regarded these analyses as exploratory. Finally, we expected that participants who would be aware that a deviation occurred would have better memory of the stories than participants who would not be aware of a deviation (Rubínová, et al., 2020).

Method

Design

This study was a 4 (story: 1/2/3/4) × 4 (session: 1/2/3/4) × 2 (content: typical/deviation) × 2 (order: typical/deviation) mixed design. Content and order were between-subjects factors; story and session were within-subjects factors.

Participants

Sample

One hundred and forty-nine participants took part in this experiment. Participants were recruited through the university undergraduate participant pool and received 2 research credits for completing the study. We used the following inclusion criteria: age over 18 years, normal or corrected-to-normal vision and hearing, and fluent English-speaking ability. There were 38 males and 111 females aged between 16 and 64 years ($M = 20.15$, $SD = 6.02$). Data from one female participant were excluded from the final sample due to familiarity with the materials.[23] All participants declared that they were fluent in English and that they had normal or corrected-to-normal vision and hearing. Participants were randomly allocated to one of four conditions: there were 37 participants in the typical content and order condition, 39 participants in the changed content condition, 36 participants in the changed order condition, and 36 participants in the changed both content and order condition.

Partially missing data and exclusions

We had complete data from 129 participants and partial data from 19 participants. Partial or complete recall from Session 1 was missing from five participants due to a technical fault. Data from Session 2 and 4 were missing from one

[23] The participant was a research assistant of a colleague and was exposed to the story videos on multiple occasions prior to signing-up for the experiment.

participant, two participants did not complete Session 3 and 4, and a further six participants did not complete Session 4. We additionally excluded partial data from Sessions 3 and 4 from five participants whose recall was identical to one of the previous online sessions (i.e., including typos; participants probably saved a record of their recall and copy-pasted it in later sessions). For further details and explanations of data exclusion see OSM (https://osf.io/jhrtc/).

Materials

The stimuli were adapted from Ahn et al. (1992, Experiment 2). We simplified and shortened their passage of a Korean Wedding Ceremony (see Ahn, et al.,1992, Appendix A), and varied details and wording of some parts to create four stories depicting the same event (please note that these stories were not labelled as a wedding ceremony; see Table 4 for a list of story-specific details and Appendix C for an example story). The stories were presented as videos showing hand-drawn illustrations of the scenes.[24] Each story was read-out by one of four native English speakers (two younger-adult male and female voices and two older-adult male and female voices; for all video examples, see OSM, https://osf.io/jhrtc/). The order of stories was counterbalanced across participants.

Table 4
List of story-specific details

	Story			
Detail	1	2	3	4
Female	Barbara	Susan	Linda	Jennifer
Male	Michael	Robert	James	Richard
Go-between	Mrs Smith	Mr Jones	Ms Evans	Mrs Lewis
Relation	Aunt	(Father's) friend	Cousin	Grandmother
Feature	Character	Nature	Personality	Interests
Delay	Two days later	Three weeks later	Twenty days later	The following day
Figure	Psychic	Forecaster	Fortune-teller	Spiritualist
Date	3rd March	12th September	11th January	9th June
Clothes	White blouse and green skirt	White dress	Blue shirt and white skirt	Yellow dress
Refreshments	Cake and fruit	Chocolate cake	Fruit cookies	Lime cake
Context	Standing next to a wooden pillar	Looking at them	Smiling at his wife	Raising glass to propose a toast

[24] We decided to present the stories in an audio-visual form (rather than asking participants to read the stories from text) because we believed that this would increase participants' engagement with the materials.

Each participant watched four stories. Stories 1—3 were a variation on the same event and served to establish the schema. Depending on the condition, changes were introduced in the fourth story. In the typical content and typical order condition, the final story was another variation on the same event. In the deviation content conditions, the ritualized actions of the main characters at the end of the final story were changed (see Themes 13 and 14 in Table 5). In the deviation order conditions, the actions of the final story remained unchanged, but were revealed in a different order in the middle part of the story (the beginning and ending remained the same; see Table 5). The stimuli were counterbalanced across participants (see OSM, https://osf.io/jhrtc/).

Procedure

Session 1

After participants read the information sheet and signed informed consent, the administrator briefed them about the procedure described below and summarized that the study had three further online parts for which they would receive links one day, one week, and one month later (participants were not told what the purpose of the online parts was, only that they would need approximately 15 minutes to complete each of them). The whole experiment was administered on a computer with, a paper-based distractor task. After demographic/screening question and basic instructions asking the participants to pay attention to the stories as they would be asked to recall them later, participants watched the first video (Story 1) two times in a row. A one-minute arithmetic filler task followed, after which instructions for immediate recall appeared: "Now please type in as much as you can remember from Story 1. Try to ensure that your reproduction is as close to the original story as possible, including as many details as you can. Take your time and revise your reproduction until you cannot remember any more. Please do not guess. Once you cannot remember any more, please continue to the next task." A two-minute dot connecting distractor task followed. The exact same procedure (including watching each story twice) was then repeated for Stories 2, 3, and 4. Participants then completed a 10-minute visual-spatial distractor task. The first delayed recall task followed: participants were asked to recall as much as they could remember from each story. The recall task was presented on four pages entitled with "Story 1" (page 1, "Story 2" on page 2, etc.) and illustrations of the boy and the girl as cues (participants could switch between the pages).

Table 5
Changes in story themes in four conditions

Theme/ Changes	Both typical	Content deviation	Order deviation	Both deviation
1/No	The couple is introduced	[1]	[1]	[1]
2/Order	The go-between visits the girl's family	[2]	[4] The boy's parents visit a 'medium'	[4]
3/Order	The go-between introduces the boy	[3]	[5] The 'medium' provides a date to send a gift to the girl	[5]
4/Order	The boy's parents visit a 'medium'	[4]	[6] The girl receives a gift	[6]
5/Order	The 'medium' provides a date to send a gift to the girl	[5]	[7] The girl receives clothes	[7]
6/Order	The girl receives a gift	[6]	[2] The go-between visits the girl's family	[2]
7/Order	The girl receives clothes	[7]	[3] The go-between introduces the boy	[3]
8/Order	A discussion between the pairs of parents	[8]	[10] The boy bows to the girl's father	[10]
9/Order	The boy wears blue clothes	[9]	[11] The boy gives the girl's father a wooden goose	[11]
10/Order	The boy bows to the girl's father	[10]	[12] Refreshments	[12]
11/Order	The boy gives the girl's father a wooden goose	[11]	[8] A discussion between the pairs of parents	[8]
12/Order	Refreshments	[12]	[9] The boy wears blue clothes	[9]
13/Content	[A] The boy and the girl bow to each other	[B] The boy and the girl sit next to each other	[13 A]	[13 B]
14/Content	[A] The boy and the girl share wine	[B] The boy and the girl sing a song	[14 A]	[14 B]
15/No	The father has a speech	[15]	[15]	[15]

Sessions 2 and 3

One day and one week after Session 1, respectively, participants received an online answer form similar to the delayed recall task described under Session 1.

Participants completed Session 2 between 0.81 and 5.91 days[25] (*M* = 1.60, *SD* = 0.71) and Session 3 between 6.08 and 15.91 days (*M* = 8.13, *SD* = 1.67). In both sessions, there were few participants at the late extremes and the smallest interval between Sessions 2 and 3 was two days, so we decided not to exclude any data from these sessions.[26]

Session 4

One month after Session 1, participants received another delayed recall online form. Participants completed this part between 27.82 and 68.09 days (*M* = 29.80, *SD* = 4.19). There were again few participants at the extreme, so we decided not to exclude any data from this session. After the recall phase, we asked participants to describe any shared elements and any differences they might have noticed between the stories. Finally, we asked participants what they thought the stories were describing.

Measures and coding

Each story consisted of 15 themes, which translated into 76 idea units (these included 11 details that varied across the stories and 4 details that were consistent but changed in the fourth story in the content deviation conditions). From the rich recall data, we created measures of quantity, source monitoring, quality, and recall organization (Sessions 1—4). From the follow-up questions (end of Session 4), we coded any mentions of the occurrence of deviations (i.e., deviation awareness), and a general event representation (i.e., what did the stories describe). Recall quantity was reflected in a coarse-grain measure of themes (maximum 15 per story; Table 4) and a fine-grain measure of idea units (maximum 76 per story; after J. M. Mandler & Johnson, 1977), both coded based on the meaning and not verbatim reproduction. Specific details were a measure of quantity that also reflected accuracy of recall (see example below). A total of 15 details was coded: 11 details that varied across stories (Table 4) and 4 details that changed in the content deviation conditions. Source monitoring was reflected in a measure of internal intrusions/source confusions of details (maximum 15 per story). Recall quality was reflected in a measure of distortions of idea units (maximum 76 per story). Recall organization was measured as the sum of pairs of

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[25] There were two participants who completed Session 2 after 6 and 11 days, respectively, and who did not complete any further sessions. In order to reduce the range of delay in Session 2, we treated these data as answers from Session 3 (see OSM, https://osf.io/jhrtc/).

[26] Excluding the participants at the extremes would not change the results.

themes that were recalled in the correct order (maximum 14 per story). Deviation awareness reflected participants' mentioning of the content and/or order deviation (yes/no). Participants' descriptions of the stories were categorized and reflected in a measure of general event representation.

Recall of themes was coded as 1 = present, 0.5 = partially present/incomplete, or 0 = absent themes. Recall of idea units was coded as 1 = present or 0 = absent; recall of details was coded as 1 = correctly recalled or 0 = incorrectly recalled/absent. Details that were attributed to an incorrect story were coded as internal intrusions. For example, the following passage: "James'[1] family *friend*[2] Ms Evans[3] visited[4] Linda's[5] parents[6] […] and told[7] them about James'[8] education[9] and personality[10]" was coded as 2 themes (Theme 2 and 3 in Table 5), 10 idea units (each marked with a superscript), 2 details (underlined), and 1 internal intrusion (in italics). For statistical analyses, themes, idea units, details, and internal intrusions were converted into a proportion.

Qualitative recall measures reflected five types of recall transformations that were, for the purpose of statistical analyses, combined into a single measure of distortions (see Bergman & Roediger, 1999). (1) Confusions were operationalised as idea units that confused actions or characters in a story (e.g., "*Linda's* cousin told Linda's mum about James"). (2) Conventionalizations were operationalized as transformations of idea units according to Western cultural schemata (Bartlett, 1932; e.g., "Once they *exchanged vows*, they sang a traditional song together", "…she received a *wedding dress*"). (3) Confabulations were mentions of idea units that were not presented in the stories (e.g., "They had fruit biscuits and *Milk* at the ceremony"). (4) Confusions from multiple sources were details that contained information originating from several other stories and showed, rather than source confusion, blending of details from multiple stories (e.g., "Mrs Smith who told Barbara's parents about Michael's education, *interests* and *personality*"). (5) Deviation confusions reflected confusions of details that changed in the content deviation conditions with typical details and vice versa.

To measure recall organization, each recalled theme was assigned a sequential number and all correct sequences were summed (e.g., themes ordered as 1, 2, 5, 6, 4, 3 include 2 correct sequences: 1, 2, and 5, 6). In order to make this measure independent of quantity of recall, we calculated a proportion in the following way: we divided the sum of correct sequences by the number of recalled themes deducted by 1 (e.g., the sequence score for the previous example—2 out of 5 correct sequences—would be 0.40, and a completely accurate sequence of any number of themes would gain a score of 1).

For deviation awareness, any mentioning of change of the ritual at the end of the story was coded as awareness of the content deviation (e.g., "In the last story the boy and girl sat next to each other and sang a traditional song instead of bowing to each other and exchanging three drinks"); any mentioning of the change of story order was coded as awareness of the order deviation (e.g., "The order of events leading up to the ceremony changed"). Please note that we coded any mentioning of deviation(s) as deviation awareness, including imprecise descriptions or attributions of the changes as (e.g., "The storyline for the first two were the same; the last two stories changed slightly" was coded as awareness of the order deviation). General event representation was categorized based on participants' descriptions of the meaning of the stories (e.g., "Arranging some kind of ceremony in which the boy and girl may eventually get married" was coded as "marriage"; see Appendix C).

All reproductions were coded by E. R. To obtain an estimate of inter-rater reliability, two subsets (a random selection of 15 participants each) were independently coded by two trained raters with resulting high agreement (Cohen's kappa between 0.72 and 0.89 for measures of themes, idea units, details, and recall organization). E. R.'s codes were used for statistical analyses. The respective data and coding manual are available in OSM (https:// https://osf.io/jhrtc/).

Statistical analyses

All measures were analysed using linear mixed models (LMM) with fixed effects of session (1/2/3/4), story (1/2/3/4), content (typical/deviation), and order (typical/deviation) with all interactions, and random intercepts for participants and random slopes for session (Finch, et al., 2014). Due to the number of effects in the full model and an associated risk of increasing Type I error, we report analyses relevant for our hypotheses in the main text (i.e., effects and interactions of session and deviation(s) and effects and interactions of story and deviation(s)) and report significant interactions involving session and story in Appendix C (we had no theory-based expectations for these effects, and there were just a few of them; https://osf.io/jhrtc/). Deviation awareness analyses, which did not differentiate between deviations, included fixed effects of session, story, and awareness (aware/not aware), and the same random effects as the previous model.

Session was treated as a continuous variable and centred. Story was coded using simple contrasts with Story 1 used as a reference level, so all models included three contrasts between Story 1 and each of Stories 2, 3, and 4. Content and order deviations were coded using simple contrasts, so the main effect of each factor represented a contrast between the typical and deviation levels; deviation awareness was coded using simple contrasts, so the main effect contrasted participants who were and who were not aware of any deviation. All significant higher-order interactions that involved session or story and any deviation were followed up with analyses at the level of stories. Data and R script are available as OSM (https://osf.io/jhrtc/).

Results

The results section is split into three parts. First, we report immediate recall results bearing on recall quantity (themes, idea units, and details) and quality (distortions) related to schema formation. This is followed by delayed recall findings focusing on general performance differences across the stories, forgetting, and deviation effects. Finally, we report analyses of deviation awareness and its relation to recall.

Immediate recall and schema formation

Figure 9 shows the increase in immediate recall of idea units across the four stories (see Table 6 for other measures). As expected, having encountered a previous example of an unfamiliar story helped participants remember the next example better, although there was not much of a further increase for Stories 3 and 4, suggesting that a new schema may have been established already after the first two instances. Recall of story themes, units, and details increased by 16%, 17% and 19%, respectively, between immediate recall of Story 1 and Story 2 (themes: $b = 0.16$, 95% *CI* [0.14, 0.18], $t(420) = 16.28$, $p < .001$; units: $b = 0.17$, [0.15, 0.19], $t(419) = 18.30$, $p < .001$; details: $b = 0.19$, [0.16, 0.21], $t(419) = 13.51$, $p < .001$). We do not report further contrasts between Story 1 and Stories 3 and 4 as they both show significant increases. There was one significant three-way interaction between story and both deviations indicating that in contrast with Story 1, recall of Story 3 was lower when both deviations were present. A follow-up analysis of Story 3, however, did not reveal any significant results (highest

t = 1.17, lowest p = .25), which means that the interaction depended on the difference between Story 1 and 3 and not on the deviation effect.

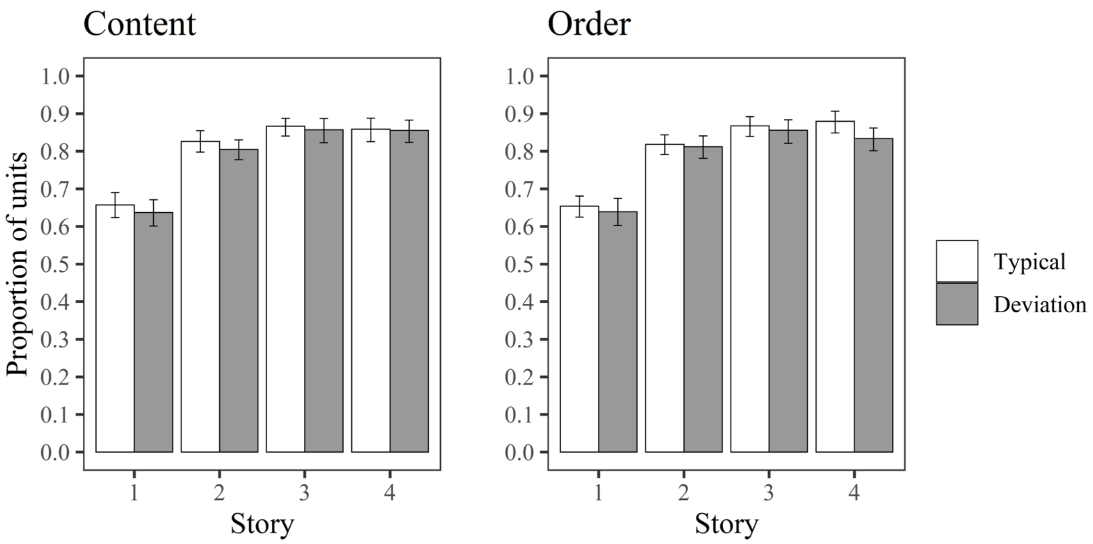

Figure 9. Immediate recall of idea units for typical/deviation content and order conditions. Error bars represent 95% *CI*s of the means.

Table 6
Proportion of themes, idea units, and details, and number of distortions in immediate recall

	Story			
Measure	1	2	3	4
Themes	0.71 (0.15)	0.87 (0.12)	0.92 (0.12)	0.91 (0.12)
Idea units	0.65 (0.15)	0.82 (0.12)	0.86 (0.13)	0.86 (0.13)
Details	0.63 (0.19)	0.82 (0.14)	0.84 (0.15)	0.80 (0.16)
Distortions	1.34 (1.37)	1.08 (1.17)	0.80 (0.91)	0.76 (0.95)

Note. Statistics display means and standard deviations.

Participants' recall included between 0 and 6 distortions in each story (M = 0.99, SD = 1.13), and the number of distortions decreased in later stories. The decrease was gradual between Stories 1 and 3 and then levelled off (Stories 1 and 2: b = -0.26, 95% CI [-0.47, -0.04], t(420) = 2.31, p = .02; Stories 2 and 3: b = -0.28, [-0.48, -0.07], t(141) = 2.62, p = .01; Stories 3 and 4: b = -0.04, [-0.48, -0.07], t(141) = 0.47, p = .64; Table 6). To examine distortions that were in line with Western cultural schemata specifically, we compared percentages of participants whose recall involved conventionalizations across the four stories and found a broadly consistent pattern, although the differences were not significant (Story 1: 10%, Story 2: 7%, Story 3: 6%, and Story 4: 2%; $\chi^2(3, N = 576) = 7.75$, $p = .05$).

In summary, analyses of immediate recall confirmed that participants learned the story schema as they gathered more experience with the material. Participants recalled more details, units, and even whole themes in later stories with most learning occurring between the first two stories. Inversely related to the improvement in the quantity of remembered material was a change in quality—alongside building a new schema for unfamiliar story came a decrease in distortions, and this decrease was more gradual. In other words, after repeated examples, participants were able to create representations based on the material rather than deriving them from cultural schemata.

Delayed recall and deviation effects

Themes

The overall analysis showed, as would be expected, that participants recalled fewer themes as delay increased ($b = -0.09$, 95% *CI* [-0.10, -0.07], $t(132) = 10.83$, $p < .001$). In addition, there was a significant two-way interaction between story and the content deviation and a significant three-way interaction between story and both deviations. These interactions indicated that in contrast with Story 1, recall of Story 4 was lower when the content or both deviations were present. A follow-up analysis of Story 4, however, did not show a significant effect of any deviation (highest $t = 1.68$, lowest $p = .10$), which again means that the interaction depended on the difference between Story 1 and 4 and not on the deviation effect.

Idea units

Similarly to themes, the overall analysis showed forgetting ($b = -0.05$, 95% *CI* [-0.06, -0.04], $t(132) = 7.67$, $p < .001$). In addition, there was a significant effect of story indicating that recall of Story 3 was slightly higher than recall of Story 1 ($b = 0.01$, [0.0003, 0.03], $t(1946) = 1.99$, $p = .047$). There were also significant two- and three-way interactions between story and each and both deviations, all indicating that in contrast with Story 1, recall of Story 4 was lower when a deviation was present. A follow-up analysis confirmed that recall of Story 4 was 8% lower in the order deviation conditions than in the typical order conditions ($b = -0.08$, [-0.16, -0.01], $t(141) = 2.28$, $p = .03$; Figure 10). In other words, participants had difficulty recalling

Story 4 when the order changed. Table 7 displays means and standard deviations for recall of idea units split by experimental conditions.

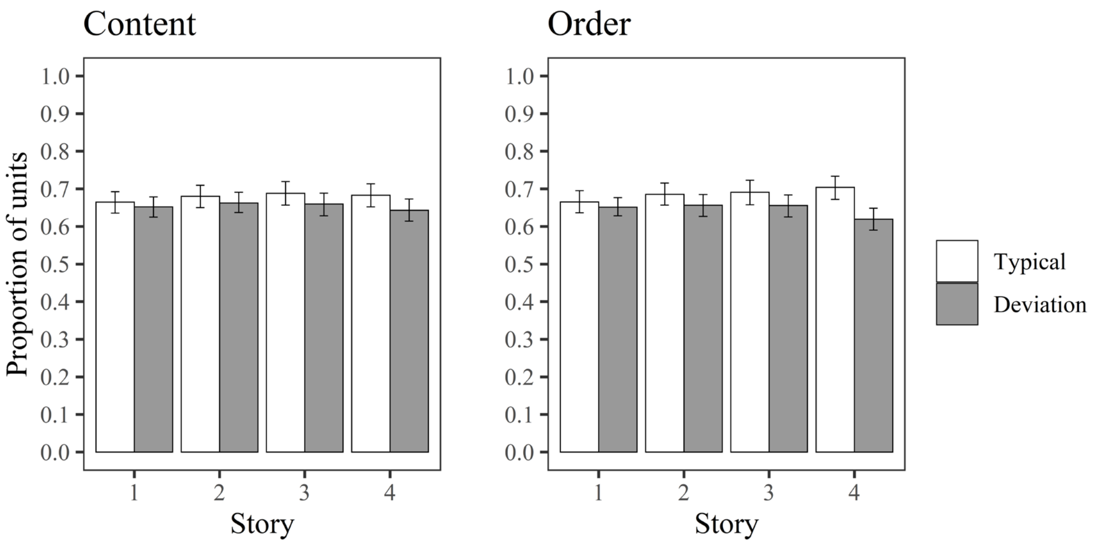

Figure 10. Delayed recall of idea units for typical/deviation content and order conditions collapsed across delay. Error bars represent 95% *CI*s of the means.

Table 7
Proportion of idea units and details in Story 4 and in all stories split by condition

	Idea units				Details			
	Story 4							
Session	Typical	Content	Order	Both	Typical	Content	Order	Both
1	.80 (.23)	.77 (.25)	.72 (.22)	.67 (.24)	.60 (.27)	.57 (.25)	.57 (.25)	.53 (.19)
2	.75 (.26)	.72 (.26)	.66 (.25)	.60 (.26)	.42 (.29)	.40 (.26)	.40 (.24)	.35 (.23)
3	.69 (.27)	.66 (.28)	.64 (.25)	.56 (.26)	.35 (.29)	.33 (.23)	.32 (.24)	.26 (.25)
4	.65 (.29)	.60 (.29)	.54 (.28)	.53 (.25)	.27 (.23)	.26 (.20)	.21 (.19)	.22 (.22)
	All stories							
1	.76 (.24)	.72 (.27)	.72 (.22)	.69 (.22)	.58 (.24)	.53 (.26)	.56 (.23)	.52 (.22)
2	.74 (.23)	.71 (.25)	.68 (.23)	.68 (.20)	.48 (.25)	.44 (.23)	.46 (.22)	.45 (.21)
3	.68 (.27)	.65 (.27)	.63 (.25)	.62 (.22)	.41 (.24)	.38 (.23)	.38 (.23)	.38 (.23)
4	.64 (.28)	.58 (.29)	.56 (.27)	.57 (.22)	.33 (.21)	.29 (.20)	.30 (.20)	.30 (.21)

Note. Typical = typical content and order; Content = deviation content and typical order; Order = typical content and deviation order; Both = deviation content and order. Statistics display means and standard deviations. Deviation details (and parallel details in typical content conditions) were excluded in the measure of details.

Details

Similar to the previous measures, the overall analysis showed 8% forgetting between sessions (*b* = -0.08, 95% *CI* [-0.09, -0.07], *t*(129) = 17.70, *p* < .001; Table 7). There was some indication of a primacy effect, as recall of Story 2 was significantly lower than recall of Story 1, although the effect was very small (*b* = -0.02, [-0.03, 0.0009], *t*(1949) = 2.07, *p* = .04). Recall of Story 4 was slightly higher than recall of Story 1 (*b* = 0.02, [0.0006, 0.03], *t*(1949) = 2.02, *p* = .04), suggesting a small recency effect. In addition, there were significant two- and three-way interactions between story and each and both deviations in the contrasts between Story 1 and Stories 3 and 4. Follow-up analyses of Story 3 and 4 revealed that recall of Story 4 was 8% lower in the content deviation conditions than in the typical content conditions (*b* = -0.08, [-0.15, -0.01], *t*(143) = 2.31, *p* = .02; see Figure 11 and Table 7); there were no significant deviation effects analyses of Story 3 (highest *t* = 1.79, lowest *p* = .08).

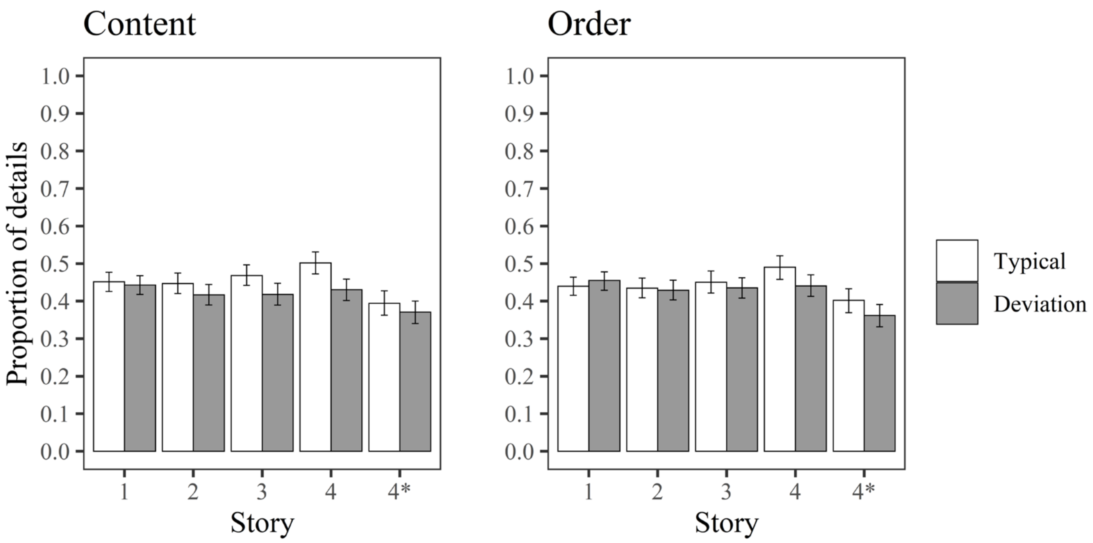

Figure 11. Delayed recall of story details for typical/deviation content and order conditions collapsed across delay. Asterisk indicates measure of details excluding deviation details (and parallel details in typical content conditions). Error bars represent 95% *CI*s of the means.

In order to find out whether the recall disruptive effect of the content deviation in Story 4 was due to participants not reporting the deviation details, we ran a parallel analysis in which we excluded details that deviated in Story 4 in the content deviation conditions and parallel details in the typical content conditions.[27] The results suggested that this was the case: there were no significant differences in recall of Story 4 between the deviation content and typical content conditions after removal of the deviation details (b = -0.03, 95% *CI* [-0.10, 0.04], $t(143) = 0.94$, $p = .35$; see Figure 11). This pattern of results was contrary to our prediction—we expected the content deviation to be well remembered and to improve recall.

Internal intrusions

In each story, there was a maximum of 15 details the source of which could have been confused with another story. Results of the main analysis revealed a non-significant effect of session, indicating that such internal intrusions were relatively stable across delay (b = 0.0001, 95% *CI* [-0.004, 0.004], $t(141) = 0.01$, $p = .995$). Next, there were main effects of story revealing that participants showed more internal intrusions in Story 2, 3, and 4 than in Story 1, a pattern that shows indirect support for the primacy effect (Story 2: b = 0.04, [0.03, 0.04], $t(1962) = 8.10$, $p < .001$; Story 3: b = 0.06, [0.05, 0.06], $t(1962) = 12.81$, $p < .001$; Story 4: b = 0.02, [0.01, 0.03], $t(1962) = 4.41$, $p < .001$; Figure 12). Finally, there was a significant interaction between story and order indicating that when contrasted with Story 1, there were fewer internal intrusions in Story 4 when order deviated than when order was typical. A follow-up analysis of Story 4 confirmed this pattern (b = -0.02, [-0.04, -0.003], $t(144) = 2.24$, $p = .03$; Figure 12).

[27] We re-calculated the measure in the following way: from recall of Story 4 in all conditions, we excluded four details that changed in the content deviation; then, we calculated a proportion of these 11 details.

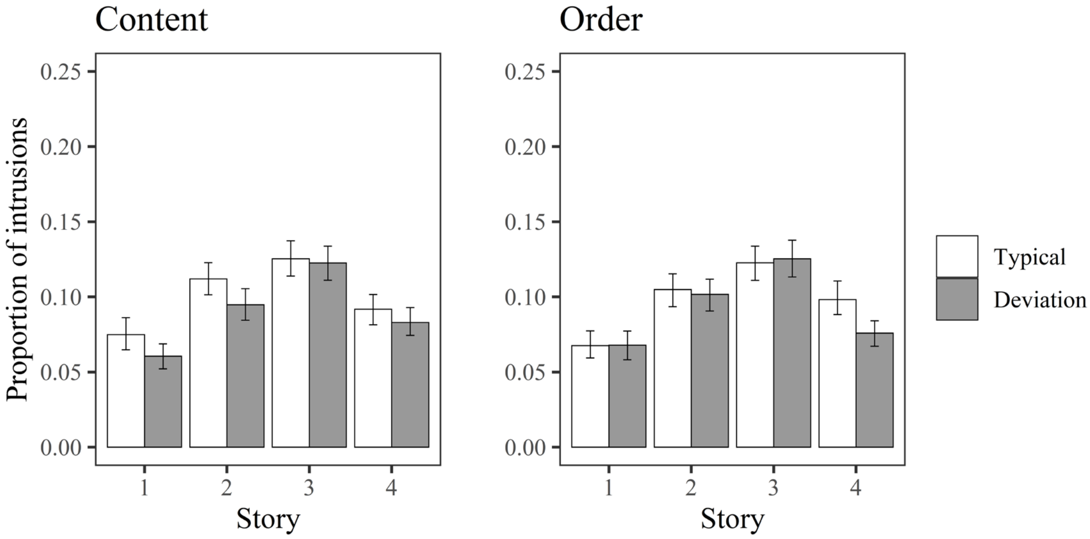

Figure 12. Internal intrusions in delayed recall for typical/deviation content and order conditions collapsed across delay. Error bars represent 95% *CI*s of the means.

Distortions

There were between 0 and 8 distortions in delayed recall. The main analysis showed a significant effect of session: there were more distortions as delay increased (b = 0.06, 95% *CI* [0.008, 0.12], $t(140) = 2.21$, $p = .03$), although the effect was very small and the most substantive increase occurred between Session 1 and 2 (Session 1: M = 1.05, SD = 1.19; Session 2: M = 1.25, SD = 1.22; Session 3: M = 1.20, SD = 1.28; Session 4: M = 1.27, SD = 1.37). In addition, a significant two-way interaction between story and content indicated that in contrast with Story 1, more distortions were reported in Story 4 in the content deviation conditions. A follow-up analysis of Story 4 confirmed this pattern (b = 0.63, [0.30, 0.97], $t(141) = 3.72$, $p < .001$).

Similar to the analysis of recalled details, we wanted to find out if the increase in recall of distortions in Story 4 associated with the content deviation was driven by participants' distortions of the deviation details. Therefore, we conducted an analysis in which deviation details and parallel details in typical content conditions were excluded from recall of Story 4.[28] The results revealed a non-significant effect of content (b = 0.002, 95% *CI* [-0.002, 0.005], $t(142) = 0.92$, $p = .36$; Figure 13),

[28] In order to create a measure that would be comparable across all stories, we calculated distortions as a proportion of units in the following way: we divided the number of distortions by 76 for Stories 1, 2, and 3, and by 72 for Story 4 (deviation details excluded).

suggesting that participants in the content deviation conditions distorted their recall of the Story 4 deviation details in particular.

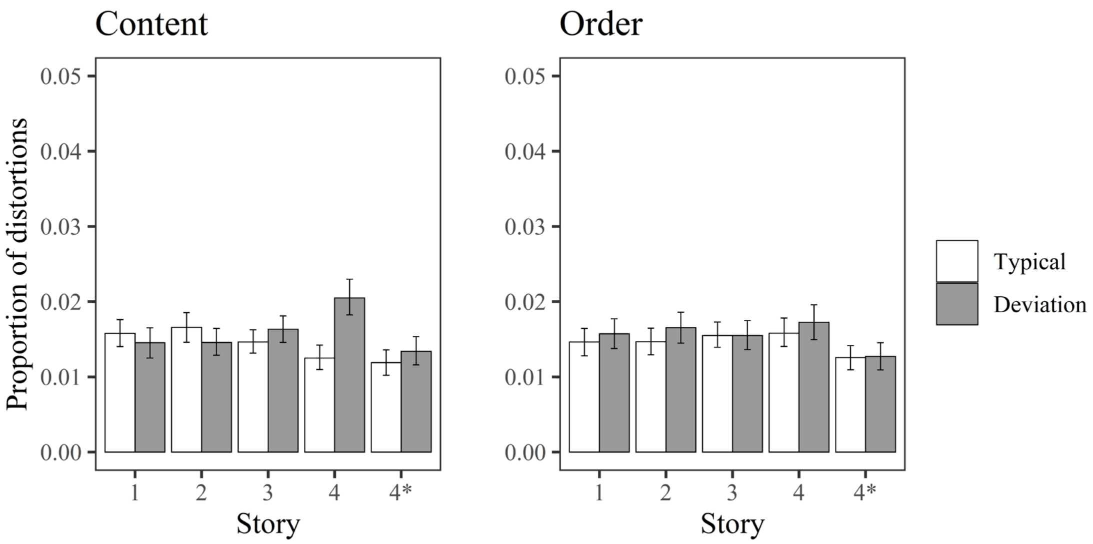

Figure 13. Distortions as a proportion of idea units in delayed recall for typical/deviation content and order conditions collapsed across delay. Asterisk indicates measure of distortions excluding deviation details (and parallel details in typical content conditions). Error bars represent 95% *CI*s of the means.

A focused analysis of conventionalizations revealed a pattern consistent with the general distortion analysis: the percentages of participants demonstrating conventionalizations in recall increased with delay from 4% to 5%, 6%, and 9% across sessions ($\chi^2(3, N = 2276) = 12.91, p = .005$) and there were no significant differences across stories ($\chi^2(3, N = 2276) = 3.01, p = .39$). Conventionalizations were more frequent among participants in the deviation content conditions than in the typical content conditions (8% vs 4%, respectively, $\chi^2(3, N = 2276) = 20.06, p < .001$; there were no significant differences between typical and deviation order conditions, $\chi^2(3, N = 2276) = 1.15, p = .28$).

Recall organization

Our main interest in looking at recall organization was to see if any potential decrease in recall due to order deviation (i.e., lower recall of idea units in Story 4) would be paired with lower correct sequencing. The main analysis revealed main effects of session and story showing a decrease in correct sequencing as delay increased (b = -0.06, 95% *CI* [-0.08, -0.05], $t(130) = 8.04$ $p < .001$) and lower correct sequencing in Stories 3 and 4 than in Story 1 (Story 3: b = -0.03, [-0.06, -0.01], $t(1952) = 2.36$, $p = .02$; Story 4: b = -0.08, [-0.10, -0.05], $t(1952) = 5.31$, $p < .001$). There was also a significant two-way interaction between story and the order deviation indicating lower correct sequencing in Story 4 than in Story 1 in order deviation conditions, which was confirmed in a follow-up analysis of Story 4 (b = -0.16, [-0.22, -0.09], $t(133) = 4.79$, $p < .001$; Figure 14).

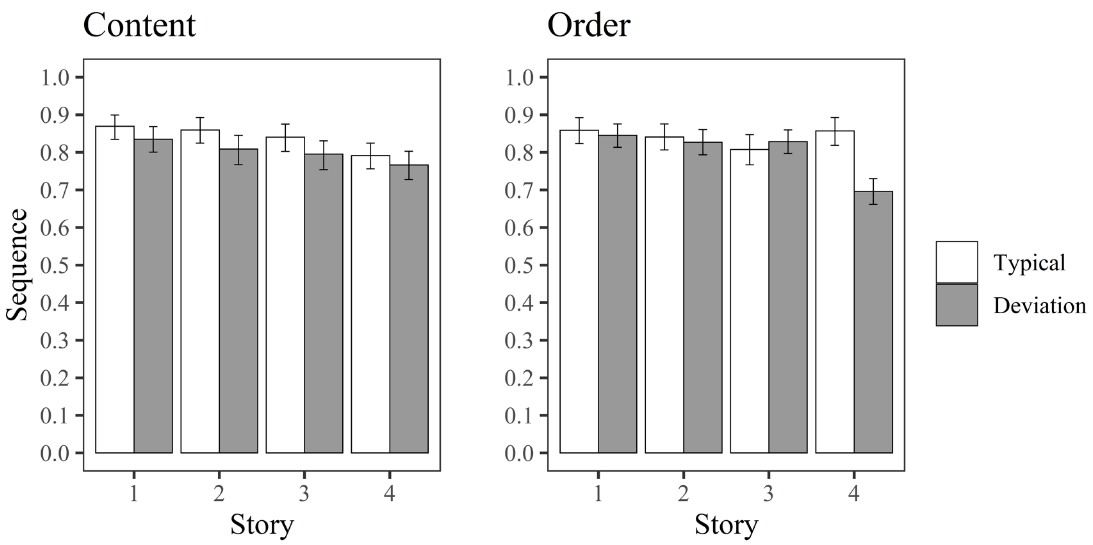

Figure 14. Sequencing in delayed recall for typical/deviation content and order conditions collapsed across delay. Error bars represent 95% *CI*s of the means.

What do analyses of delayed recall tell us overall? All measures of recall quantity showed forgetting with time. Distortions in recall, however, increased with delay—a pattern that may indicate the perseverance of transformations (including those guided by old cultural schema). Next, we found very small direct support for general primacy and recency effects (we will elaborate on three indirect indicators of primacy in the Discussion section, though). With regards to deviation effects, the content deviation impacted recall in the opposite direction than we expected based on previous literature using familiar materials. Participants in the content deviation conditions recalled fewer details and more distortions in Story 4, largely because they failed to report and/or transformed the deviation details. The order deviation, however, showed an expected effect: participants reported (i) fewer idea units from Story 4 and (ii) were less able to recall the story according to the sequence it was revealed when the order deviated. We now turn to analyses pertaining to deviation awareness.

Awareness of schema disruption

At the end of the final delayed recall protocol, we asked participants to describe any changes between the stories they might have noticed. Twenty-seven participants mentioned that a change of the ritual that the couple performed occurred, which was coded as awareness of the content deviation (44% of participants in the content deviation conditions), and 25 participants mentioned a that a change in the order of the events in a story occurred, which was coded as awareness of the order deviation (41% of participants in the order deviation conditions).

Awareness of any deviations and recall of themes, idea units, and details

Our main interest in looking at deviation awareness was to see if awareness of any deviation would be associated with better recall. We found that participants in the deviation conditions who reported a deviation recalled 11% more story themes ($b = 0.11$, 95% *CI* [0.03, 0.19], $t(92) = 2.76$, $p = .007$), 12% more story units ($b = 0.12$, [0.04, 0.20], $t(92) = 2.96$, $p = .004$), and 8% more details ($b = 0.08$, [0.008, 0.15], $t(92) = 2.18$, $p = .03$) than participants who did not report that a deviation occurred. In addition, for each measure, there were significant interactions between awareness and story suggesting that the effect of awareness was stronger in recall of Story 4 than in Story 1. Follow-up analyses of Story 4 confirmed this pattern for themes ($b = 0.15$, [0.04, 0.26], $t(92) = 2.76$, $p = .007$), idea units ($b = 0.15$, [0.07, 0.24], $t(92) = 3.44$, $p < .001$), and details[29] ($b = 0.12$, [0.04, 0.20], $t(92) = 2.75$, $p = .007$; Figure 15).

Awareness of any deviations and internal intrusions and distortions

Deviation awareness was not associated with significant differences in internal intrusions ($b = -0.006$, [-0.03. 0.01], $t(92) = 0.60$, $p = .55$) and distortions ($b = 0.009$, [-0.31, 0.33], $t(92) = 0.06$, $p = .96$).

Awareness of any deviations and recall organization

The main effect of deviation awareness was not significant ($b = 0.06$, 95% *CI* [-0.001, 0.13], $t(92) = 1.92$, $p = .06$), but there was an interaction between awareness and story specifying that in contrast with Story 1 (where there was no difference in sequencing based on deviation awareness), sequencing of Story 4 was higher for participants who reported a deviation than those who did not report a

[29] A parallel analysis with details excluding deviation details (and parallel details in typical content conditions) showed a consistent effect ($b = 0.10$, [0.01, 0.18], $t(92) = 2.31$, $p = .02$).

deviation. A follow-up analysis of Story 4 confirmed this pattern (*b* = 0.09, [0.01, 0.17], *t*(92) = 2.31, *p* = .02; Figure 15).

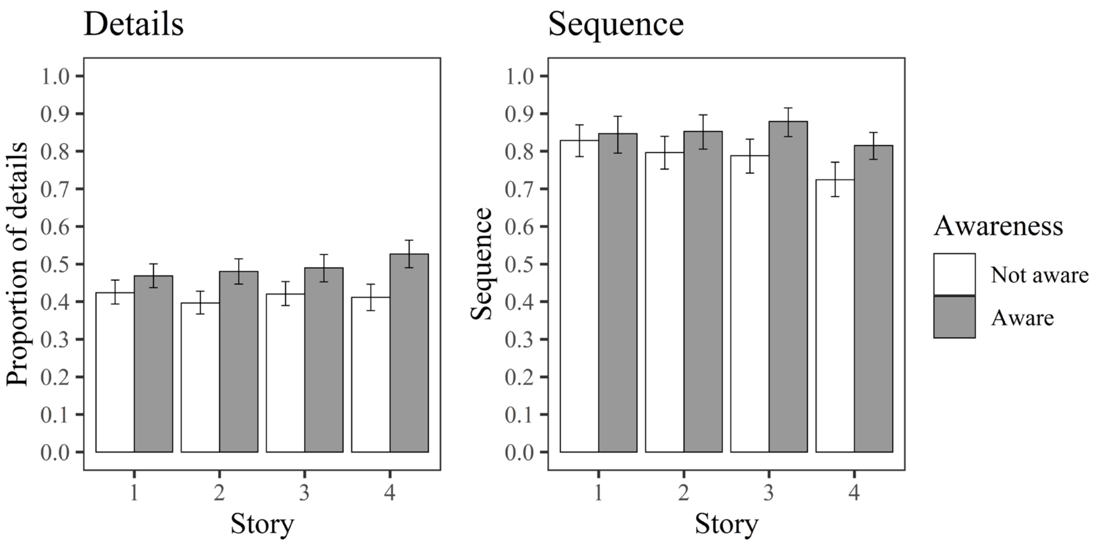

Figure 15. Deviation awareness and recall of detail and sequencing in delayed recall for typical/deviation content and order conditions collapsed across delay. Error bars represent 95% *CI*s of the means.

Overall, there were similar—and relatively low—levels of reporting the content and order deviation. This pattern, at least in case of the surprisingly low degree of reporting the content deviation (relative to previous research; Rubínová, et al., 2020), complements low recall of deviation details: it seems that participants did not pay much attention to the deviation details (or in general). Analyses of deviation awareness and overall recall confirmed this idea: participants who reported that a deviation occurred remembered more than participants who did not report a deviation, and this effect was strongest in Story 4, where deviation awareness was also associated with better recall organization.

Discussion

Imagine a European couple participating in a series of Japanese tea ceremonies or employees in a manufacture adjusting to machine production. In both scenarios, those involved (need to) become familiar with a completely new and perhaps strange environment. Learning would likely entail a series of repeated events and would lead to the emergence of a new knowledge structure—a schema. We aimed to study memory processes in such scenarios by presenting participants with four versions of an unfamiliar story and measuring their learning and delayed recall with delays increasing from ten minutes up to one month after presentation.

General and schema effects in recall of repeated unfamiliar events

In immediate recall of each story, we found that memory performance improved as participants learned more stories. Improvement was quantitative and qualitative. Quantitatively, participants reported more themes, idea units, and story-specific details in later stories. This pattern suggested that the representation of the first story served as "scaffolding" for the recall of later stories and as foundation for the building of a new schema (e.g., Brewer & Nakamura, 1984; Ghosh & Gilboa, 2014; Minsky, 1974; Schank, 1999). Qualitatively, distortions of parts of the stories, including conventionalizations that were in line with Western cultural schemata (Bartlett, 1932), occurred less frequently in immediate recall of later stories. This pattern of substituting early distortions with new accurate representations suggested a process of gradual separation of the new schema (emerging through experience with the stories) from old cultural schemata through which participants, at least partly, initially comprehended and interpreted the stories (e.g., Cole & Cole, 2000).

In delayed reproduction, measures of quantity and accuracy of recall indicated forgetting while reporting of distortions slightly increased, which is consistent with results from studies investigating repeated retrieval of a single unfamiliar story (Bergman & Roediger, 1999; Wagoner & Gillespie, 2014). In addition, the perseverance of distortions in recall suggested that old cultural schemata remained blended into the new schema (e.g., mentioning that the couple "exchanged vows" at the end of the ceremony), where they served a function of conserving memory (Ost & Costall, 2002).

Delayed recall analyses showed, contrary to our expectations, only a limited direct support for primacy and recency effects in the recall of details. Indirectly, however, there were three indicators of a primacy effect. First, comparing Figures 1 (immediate recall) and 2 (delayed recall), we find that recall of Story 1 remained stable (at ~65%), while recall of the other stories decreased by almost 20% on average (themes and details showed similar patterns). Second, analyses of delayed recall of details (reported in Appendix C and in OSM) revealed that participants forgot details from Stories 2, 3, and 4 faster than details from Story 1. Third, details of Story 1 seemed to have stronger source links as more source confusions occurred in the other stories. In brief, the first story was more immune to forgetting than the consecutive stories (see Connolly, et al., 2016; MacLean, et al., 2018; Roberts, et al., 2015; Rubínová, et al., 2020), but a direct primacy effect was probably obscured by a concurrent schema-establishment effect (as seen in Figure 9).

Deviation effects and deviation awareness in delayed recall of repeated unfamiliar events

Next, our study investigated the effects of content and order deviations on recall. Previous research using familiar materials indicated that a content deviation may lead to an increase in recall (e.g., Davidson, 1994; MacLean, et al., 2018), while an order deviation may lead to a decrease in recall (Rubínová, et al., 2020). Our results were, however, only partly consistent with previous findings. Notably, participants had difficulty remembering the content deviation details, and these details became distorted more often than typical details.[30] The order deviation had an expected negative effect on recall, although it was limited to Story 4. This lower recall was accompanied by lower level of recall organization—participants often failed to recall themes of the final story in the sequence in which they were presented, a finding that is in line with previous research (Rubínová, et al., 2020). Why were these effects limited to the story in which the deviation occurred, and why did we find an opposite effect of the content deviation? As we will elaborate below, we speculate that due to the use of complex unfamiliar stimuli, schema development in our study may have been at earlier stages than in previous studies.

It is assumed in repeated-event research using familiar materials that new schemata are established with the early instances and that each consecutive instance strengthens the schema (Fivush, 1984). Farrar and Boyer-Pennington (1999; see also Farrar & Goodman, 1992) use “schema-confirmation” as a term for the first stage of schema development, in which individuals look for a reference that would help them comprehend the experience. In the process of schema-confirmation, schema-typical details receive attention until an appropriate reference schema is found, and the authors

[30] Connolly et al. (2016, Experiment 3) reported a similar pattern when they compared reports about a deviation between children from two deviation groups. Children from a discrete interruption group reported more incorrect details about the deviation than children from a group in which the interruption lead to a change in behaviour of the main actor for the rest of the event. The nature of this comparison is, however, different from our study, where we compared recall of specific details that were either typical or deviated.

emphasise that at this stage, information is remembered only if it is part of the schema, which is unlikely for instance-specific or deviation details (Farrar & Boyer-Pennington, 1999). Only once a reference schema is confirmed, a second stage (termed "schema-deployment") can follow, during which attention can "be directed toward the processing of new, and possibly inconsistent, information" (1999, p. 268). Critically, according to the authors, processing may not at all reach the second stage when new schemata are developing due to attention demands (1999; see also Danby, et al., 2019).

Our findings are consistent with this model and suggest that schema development did not reach the second stage: in delayed recall, deviation details were scarcely reported and often distorted, and participants had difficulty remembering the sequence of a story that unfolded in a different order. In addition, deviation awareness was relatively low (~40% for both content and order deviation). It seems that participants did not have attentional resources that would enable them to process the deviation details or to encode the new sequence—they were only able to maintain information that was consistent with the emerging schema (Farrar & Boyer-Pennington, 1999; Farrar & Goodman, 1992). Findings from previous studies using familiar materials would, in contrast, fit with the second stage of schema development. There, content deviation was associated with high awareness (Rubínová, et al., 2020), and content deviation effects were explained through active processing of the deviation and contrasting the deviation instance with typical instances, thus leading to enhanced recall of the deviation details, the whole deviation instance, or all instances in the series (Connolly, et al., 2016; MacLean, et al., 2018). The order deviation, as reported by Rubínová et al. (2020), was associated with low awareness, and the order deviation effects were explained through undermining the newly established simple schema, thus leading to disrupted recall of the whole series of instances.

Finally, our study investigated deviation awareness and its role in recall. In line with our predictions, reporting a deviation was associated with higher recall, and the difference was most apparent in recall of the deviation story (Story 4). This relationship supports the idea that participants who paid more attention to the materials (i) more frequently noticed or remembered that a deviation occurred, and (ii) had overall better memory of the stories.

Limitations

This study had two main limitations. First, we administered all stories during one session, which is an unlikely (although not impossible) scenario for repeated events occurring in daily life where instances may be separated by days, weeks, or even months. There were mainly practical reasons leading to this methodological decision—conducting this study across multiple days while maintaining the sample size would not have been feasible for us, so we needed to admit some reduction in external validity. On the other hand, single-session (as opposed to spaced) presentation might have contributed to faster schema development (Price, et al., 2006). Second, we only investigated effects of deviations that occurred in the final story. Due to the nature of our study, we wanted participants to gain as much experience with the materials as possible before introducing the deviation. We, therefore, do not know what effects we could expect if deviations were included in one of the middle stories or in the first story.

Conclusion

Our investigation is a step in broadening our understanding of cognitive processes that contribute to autobiographical memory and has potential implications for applied investigative interviewing. People may encounter events that they do not fully comprehend in various contexts. When that happens, they are likely to interpret these events through knowledge they already possess, which may lead to distortions of some pieces of information. It is only with repeated experience that better understanding of what is (and perhaps was) going on is gained and that, at least some, distortions are corrected thanks to the emergence of a new schema. An instance of a repeated event sometimes differs from other instances—there may be changes in what happens and/or in how the event unfolds. Contrary to intuition, such changes may not be remembered at all, especially if the repeated event is unfamiliar and the schema is in the early stages of development. In investigative settings, when such unfamiliar repeated events become of interest, it seems that, if there is a delay, targeting the first event during an interview may lead to most correct reporting. In addition, investigators should be sensitive to indications that an event differed. Although not many people would notice that an unfamiliar repeated event included a deviation, those who would notice and remember such deviation tend to recall more information overall.

Acknowledgements

The authors would like to thank Liz Saunders, George Burrows, Anthony Groves, and Suzy Wise, and Jana Literáková for their help with developing the stimuli; Vanessa Davis for assisting at data collection; Chloe Alexis, Pamela Korsah, and Priyanka Mistry for their help data management; and Nadine Hawkins de Namor and Ewa Skopicz-Radkiewicz for their help with reliability coding.

Chapter 4. Adults' memory for instances of a self-experienced interactive repeated event

Ethics reference: SFEC 2018-014 (Appendix E).

Abstract

Teaching a lecture, attending a Spanish language class, or completing procedures required to turn off a production line are examples of events that some people encounter repeatedly in their daily lives. A consequence of such repeated experience that results from schema formation and confusion of details is difficulty to recall specific instances. In this study, we investigated recall of typical and deviation instances of an interactive self-experienced repeated event. In the course of one to two weeks, adult participants attended four marketing-themed visits during which they experienced three activities. To investigate effects of schema-deviations on recall of instances, we implemented a deviation of content (i.e., we changed a goal of one of the activities) and/or temporal order (i.e., we changed the sequence of two activities) in the final visit. Participants were first interviewed about the visits one to two weeks after the final visit, and then again one month later. Consistently with previous research, we found a strong and stable primacy effect as a pattern of the highest number of correct details and the lowest number of confusions in recall of the first instance. The recency effect associated with the recall of the final instance was weaker and disappeared with the longer delay. We also found a predicted disruptive effect of the order deviation; the content change we implemented was probably not noticeable enough, which precluded any content deviation effects.

Introduction

For many people, the course of a typical day or week resembles the course of other days or weeks (N. R. Brown, 2016; Gioia & Poole, 1984; Neisser, 1981; Neisser, 1988; Renoult, et al., 2012). Evening routines, dance lessons, staff meetings, or machine operation procedures are just a few examples of such repeated events. Specific instances of such events share an underlying structure (a schema; e.g., each lesson involves an ordered set of usual exercises) but have limited overlap of details (e.g., the content of exercises differs at each instance). Additional variation across instances of a repeated event comes from at least three main sources. First, each instance occurs on a different day or week, depending on how frequently they repeat. Therefore, weather, clothes, mood, the presence of others, interactions, and many other contextual aspects vary. Next, an inherent property of each instance is its serial order position within the repeated event, such that each instance is either first, second, … or last. Finally, some instances contain unpredictable changes (i.e., deviations)—a teacher may create a deviation when they change the structure of a lesson or modify an exercise.

Although each set of variable details and potential deviations are unique to one instance, the overlap of shared aspects across instances of a repeated event creates interference (Postman, 1971), which consequently leads to a source confusion (e.g., Johnson, et al., 1993). In other words, in an attempt to recall details from a specific instance, one may end up recalling a mix of details that originated at that instance (i.e., correct details) and details that originated at other instances (i.e., internal intrusions; Woiwod, et al., 2019). In casual conversations about shared experiences or in high-stakes settings such as investigative interviewing where people may be required to recall details of several instances of a repeated event, such errors may be crucial (Kelloway, et al., 2004). To date, a handful of studies examined how adults remember instances of a repeated event (e.g., Connolly & Price, 2013; MacLean, et al., 2018; Rubínová, et al., in press; Rubínová, et al., 2020; Weinsheimer, et al., 2017), while the majority of research in this area targeted child samples (mainly due to the difficulty in fulfilling the requirement of instantiation in repeated child sexual abuse cases; e.g., Guadagno, et al., 2006; Woiwod & Connolly, 2017; Woiwod, et al., 2019). The current study contributed to the literature as the first investigation of adults' memory for typical and deviation instances from a complex interactive repeated event that was similar to events people experience in daily life.

Memory for typical and deviation instances of a repeated event

Repeated experience leads to the adaptation of a new schema from existing knowledge structures, and such schema then facilitates cognitive processing of further repeated experiences as well as their later memory reconstruction (e.g., Bartlett, 1932; Minsky, 1974; Rumelhart, et al., 1986; van Kesteren, et al., 2012; Schank, 1999; Schank & Abelson, 1975). Schemata are helpful in recall of typical aspects of instances (e.g., the structure and details that do not change across instances; Danby, et al., 2019; van Kesteren, Beul, et al., 2013; van Kesteren, Rijpkema, et al., 2013). Recall of specific details and their accurate attribution, however, depends on the level of cognitive processing of the details (Farrar & Boyer-Pennington, 1999; Farrar & Goodman, 1992; Greve, et al., 2019; van Kesteren, et al., 2012) and on the amount of unique characteristics that provide links between details and instances (Johnson, et al., 1993; Lindsay, 2008, 2014). There are at least two categories of instances that possess qualities that should make associated details more memorable.

First, according to the transition theory, the beginnings and endings of repeated events serve as landmarks in autobiographical memory that help maintain the temporal organization of other events (N. R. Brown, 2016). In its essence, the theory suggests that the first and the final instances of a repeated event have unique qualities. A stronger memory for the first instance may be additionally facilitated by involuntary reminding that may occur at repeated experience and during schema formation (Hintzman, 2011). Finally, memories for the first and the final instances are exposed to reduced interference from their neighbors. Resulting primacy and recency effects (i.e., patterns of more correct details and fewer internal intrusions in the recall of the first and the final instances than in the middle instances) have been widely documented, although evidence for the recency effect is mixed (Connolly, et al., 2016; Dilevski, et al., 2019; Kontogianni, et al., 2020; MacLean, et al., 2018; Powell & Thomson, 1997; Rubínová, et al., 2020).

Second, certain instances in a repeated event contain details such as highly noticeable variations or deviations that should draw attention and, in turn, become more memorable (Danby, et al., 2019; Davidson, 1994; Davidson & Jergovic, 1996; Davidson, et al., 2000; Farrar & Boyer-Pennington, 1999; Farrar & Goodman, 1992; Hudson, 1988; Rubínová, et al., 2020). A review of deviation effects on recall in the context of repeated events, however, reveals a high variability in the operationalization of deviations across studies that complicates generalizability. Deviations that have been used in repeated-event research included various kinds of disruptions, changes of main protagonists, new activities, schema-inconsistent details, and changes in temporal order (e.g, Brubacher, et al., 2011; Connolly et al.; 2016; Danby, et al., 2019; Farrar & Goodman, 1992; Greve, et al., 2019; Kontogianni, et al., 2020; MacLean, et al., 2018; Rubínová, et al., in press; Rubínová, et al., 2020). Broadly, most of these studies involved changes of what happened (i.e., *content* deviations); two studies examined *order* deviations, and one study combined both deviations.

Studies applying content deviations typically found that deviation details were well remembered and associated with increased recall of the deviation instance or all instances from the repeated event (e.g., new variations or schema-inconsistent details; Brubacher, et al., 2011; Greve, et al., 2019; Rubínová, et al., 2020). Rubínová et al. (2020) additionally reported that most participants remembered that the content deviation occurred. There are, however, also mixed findings (e.g., positive effects of interruptions with or without various consequences were found only in some age groups; Connolly, et al., 2016; MacLean, et al., 2018) and null effects (e.g., for a change of actor or a new activity combined with a changed sequence of activities; Kontogianni, et al., 2020; Farrar & Goodman, 1992).

Studies applying order deviations consistently found the opposite effects: participants recalled fewer details from the deviation instance or from all instances from the repeated event and rarely reported that the deviation occurred (Rubínová, et al., in press; Rubínová, et al., 2020). The order deviation effect that is measured at retrieval likely originates at encoding. Low saliency or subjective low importance of the order deviation may lead to its insufficient cognitive processing (Farrar & Boyer-Pennington, 1999; Farrar & Goodman, 1992; Rubínová, et al., in press). Failing to encode the deviation would result in errors because recall of the deviation instance would be guided by the old schema (Rubínová, et al., in press). Alternatively, order may be an implicit feature of the schema and the order deviations may, therefore, impact on the schema even without explicit notion; such compromised schema would then result in decreased recall across all instances from the repeated event (Rubínová, et al., 2020).

Finally, the two studies that explicitly measured deviation awareness found that being aware that any deviations occurred was associated with better recall (Rubínová, et al., in press; Rubínová, et al., 2020).

The current study

Our aim in the current study was to develop a design that would enable us to study memory for typical and deviation instances of a repeated event that would be similar to autobiographical experiences. Inspired by methodologies used in developmental repeated-event research where children are typically interviewed about instances in which they directly participated (e.g., play sessions), we created a series of interactive marketing-themed visits that would be engaging for our target sample of adults. During each of four visits, participants experienced the same three structured activities at which they interacted with, inspected, and evaluated products.

In a factorial design, we implemented the content and order deviations in the fourth and final visit. We applied the content deviation as a change in the *goal* of the final activity (i.e., instead of providing their opinion on four existing ratings of a device, participants were asked to evaluate ten features of a device). The content deviation was intended as a vivid schema-inconsistent change (i.e., for opinion ratings, participants selected whether they agree or disagree; for feature evaluation, they used an emotion-indicating graphic slider), although as will be clear from the results, this manipulation was likely not salient enough. We applied the order deviation as a change in order of the first two activities in the final visit. Participants were asked to recall what they remember from the visits one to two weeks after their final visit (in person interview) and then again four to six weeks later (online form). Our predictions were in line with previous literature. We expected: (i) primacy and recency effects, (ii) positive recall effects and more frequent reporting of the occurrence of the content deviation and (iii) the opposite effects associated with the order deviation, and finally (iii) better recall in participants who remembered that any deviations occurred.

Method

This study was preregistered on the Open Science Framework (see https://tinyurl.com/u6wpfs6). Any departures from the preregistration, data, code, materials for this study, and additional analyses can be found in OSM (https://tinyurl.com/yaswmroh) and in Appendix D.

Design

This study used a 2 (recall session: first/second) × 4 (visit: 1/2/3/4) × 2 (content: typical/deviation) × 2 (order: typical/deviation) mixed design. Session and visit were within-subjects factors; content and order were between-subjects factors resulting in four conditions (typical content and typical order, deviation content and typical order, typical content and deviation order, and deviation content and deviation order).

Participants

Based on an a-priori power analysis, our sample consisted of 128 participants (24 males, 95 females, 9 participants did not indicate gender) aged between 18 and 57 years (*M* = 22.76, *SD* = 7.69). Participants were recruited from an undergraduate participant pool and from a university noticeboard, had normal or corrected-to-normal vision and hearing and were fluent in English. The award for participation was 1 study credit and £5, or £15.

Procedure

Part 1

Individual participants came into the lab for four marketing-themed visits. The average delays in days between consecutive visits were 1.83 (*SD* = 1.03, Visits 1-2), 2.08 (*SD* = 1.12, Visits 2-3), and 1.84 (*SD* = 0.98, Visits 3-4). At each visit, participants experienced three activities: Game, Products, and Device. Table 8 shows four sets of stimuli according to activities that were used during the visits.[31] The visits were administered in a lab with a central room (Products) and adjacent rooms to the left (Game) and right (Device), so participants changed rooms for each activity.

During the Game activity, participants played a demo of a story-telling game that involved rolling dice with pictures (story elements) on each side and then creating a story from these pictures. At each visit, the experimenter introduced the game version and played first. The participants played next and then completed a brief evaluation sheet, in which they wrote down the pictures they rolled and provided ratings for quality and enjoyment of the game. The version of the game and participants' images were four critical details from this activity. The view of the table during the play was video recorded in case we needed a reference during coding (for details, see Appendix D).

During the Products activity, participants evaluated the packaging design (logo and graphics) of three products that were placed on a table. The product category and

[31] The sets used in Visit 4 were fully counterbalanced across conditions (i.e., each set was used with 8 participants in each condition). In Visits 1, 2, and 3, the sets were partially counterbalanced (i.e., each set was used with a minimum of 7 and a maximum of 9 participants in each condition).

specific products were four critical details from this activity. The order of the Game and Products activities was counterbalanced across participants. In Visits 1, 2, and 3, the order was the same for all participants (i.e., either Game-Products or Products-Game). In the deviation order conditions, the order of these activities in Visit 4 was changed (while it remained unchanged in the typical order conditions).

Table 8
List of activities and details in four sets of stimuli used across the visits

	Activities		
Set	Game (roll three dice and create a story)	Products (rate product packaging)	Device (inspect and express opinion/evaluate features)
1	Original (red box)	Shower gels (Lynx, Sanex, Radox)	Vertical mouse (draw a house, car, and a tree in Paint)
2	Voyages (green box)	Sweet treats (Lindt, Chocolate Orange, Maryland's Cookies)	White marker (draw an exclamation mark, a tick sign, and a dollar sign)
3	Actions (blue box)	Deodorants (Old Spice, Sure, Nivea)	Laser pointer (circle around a monkey, underline a horse, and cross out a chicken)
4	Fantasia (purple box)	Soft drinks (Monster, Ginger Beer, Vita Coco Coconut Water)	Decorative scissors (cut out a card, a heart, and a star)

Note. The four versions of Game differed in their themes. For example, Voyages included pictures referring to various countries, Actions depicted figures performing various actions, and Fantasia included references to fairy tales or Greek mythology.

Device, which was the last activity, had three phases. Participants first read an introduction to the task from a laptop screen, then performed three tasks with a device according to displayed instructions, and finally completed an evaluation form. The device and details of the three tasks were four critical details from this activity. There were two versions of the Device activity (Opinion and Evaluation) that were counterbalanced across participants. One of the versions served as "baseline" in Visits 1, 2, and 3, and the alternative version served as the content deviation in Visit 4 for participants in the content deviation conditions (the version remained unchanged for participants in the typical content conditions). Participants' goal in the Opinion version was to express whether they agree or disagree with four ratings of a device that were consistent with a marketing description they read during the introduction phase. In the

Evaluation version, participants' goal was to provide user ratings for ten features of a device (using an emotion-indicating face scale) that would help the experimenter to write a marketing description of the device, which was explained in the introduction phase. In summary, the versions differed in the overall goal of the activity (i.e., expressing opinion vs providing evaluations) and in graphical elements (i.e., four multiple-choice items vs ten face scale ratings).

Part 2

One to two weeks after Visit 4 (*M* = 9.39, *SD* = 1.03 days), participants came for an interview. The scripted interviews were administered in a different room by one of seven trained interviewers (62 interviews were administered by E. R. and 66 by another interviewer). The interviews had two phases. Participants were first asked to complete a written account of each visit using an A3 sheet with four windows (one for each visit). Participants were asked to write a complete report about each visit including as many details as possible without guessing. This format was intended to provide participants with a visual overview of all the visits (similar to the timeline technique; Hope, et al., 2019; Hope, Mullis, & Gabbert, 2013). To provide participants with an additional free-recall prompt and an opportunity to reflect upon their written accounts, we asked them to provide a verbal account of each visit followed by an open prompt ("Is there anything else you can remember about this visit?") and one final prompt at the end of the interview ("Is there anything else you would like to report?"). The verbal interview was audio-recorded.

Part 3

Four weeks after Part 2, participants were emailed an online recall form that consisted of four blank pages and instructions similar to Part 2. Eighty-four participants completed this part with an average delay of 35.28 days (*SD* = 5.48). Following the recall part, we asked participants two questions that were used for coding participants' awareness of the occurrence of the deviation(s): "Did you notice any similarities across the visits?", and "Did you notice any differences across the visits?". Later during data collection (for the final 52 participants of which 34 completed Part 3), we added description of the deviations (i.e., changes in the Device activity and changes of the order of activities) and asked participants if they noticed any of these changes. If they responded "Yes", we asked them to provide a description.

Measures

Recall measured included: (i) schematic recall of visits (i.e., ordered activities); (ii) correct details, (iii) internal intrusions (misattribution errors), and (iv) new details (i.e., details that did not occur during any of the visits). For statistical analyses of critical details and internal intrusions, we calculated a proportion by dividing the total number by 12 (i.e., the maximum number of details in each visit). Measures of awareness of the occurrence of the content and the order deviation were created based on participants' mentions of differences across the visits; from a sub-sample of participants, we obtained additional recognition measures of each deviation. For statistical analyses of the association between reporting the occurrence of a deviation and recall, we created a measure of general deviation awareness by collapsing awareness across deviations.

Coding

Overview

Coding involved three steps. Briefly, recall data for each visit were first sorted into activities and details, then validated according to a coding manual (see Appendix D), and then automatically coded. Written and verbal phases from Part 2 (interview) were coded separately and then combined. The combined measure included all information that was omitted during the verbal phase but mentioned in the written phase, and all information that was additionally recalled or changed in the verbal phase (for a comparison of the written and verbal phases, see Appendix D).

Activities and details

In the first step, recall data were entered into a spreadsheet that contained three columns for activities and twelve columns for specific details of each visit. Activities were entered based on participants' explicit mention of an activity or based on their recall of details (e.g., "In Visit 1, I remember we played the story-telling game, and it was the Actions version…but I don't remember the dice I rolled" was entered as Game for the first activity; "Then we had chocolates for the second part, and I just remember that Maryland Cookies were there, but I can't remember the other two" was entered as Products for the second activity; "And then I got to play with a marker" was entered as Device for the third activity). The order in which activities were entered was determined by participants' explicit mention of the order or by the order in which they recalled the activities (therefore, this measure partly reflects recall organization).

In the second step, rich verbal reports were reduced and validated as activities and specific details according to a coding manual (e.g., "white-labelling pen" was validated as "white marker", "cutter with curvy shape" was validated as "scissors", and "Lindt dark chocolate with chilli" was validated as "Lindt"). Reports that were not specific enough to be recognized as a detail were coded as "vague" (e.g., "simple" for game, or "cookies" for products). Descriptions containing confusions of multiple details were coded as "confusion" (e.g., "action (red)" for game, where Actions was blue and Original was red). Details that did not occur during the visits were coded as "new" details (e.g., "Dove" for products). Omitted information was coded as "not recalled". Details pertaining to pictures on the dice game were exempt from data validation (i.e., they were coded in the third step).

In the third step, validated data were scored against a reference sheet. This process automatically coded each activity as "correct" if recall corresponded to the reference sheet, "incorrect" if it was recalled out of order, or "not recalled" if it was omitted. Validated details were coded as "correct" if they were attributed to the correct visit or as "intrusions" if they were attributed to an incorrect visit (codes for "vague", "new", and "not recalled" details were retained). Details of the dice game were coded manually. For further details of the coding procedure, see Appendix D.

Data were entered, validated, and coded by a trained research assistant (E. V.), and her scores were used for all statistical analyses. To obtain estimates of inter-rater reliability, a subset of the data was independently coded by trained research assistants (device and product details from written reports of 114 participants) and E. R. (device and game details from written reports of 126 participants). Resulting agreement was high (Cohen's kappa ranged between 0.90 and 0.97).

Deviation awareness

Mentions of differences in the Device activity that referred to a change in the form of activity were coded as "aware" of the content deviation, and any descriptions of differences in the order of activities were coded as "aware" of the order deviation (specific descriptions as well as general mentions of a different order were all coded as "aware"). Please note that in some cases, participants described the differences without making a reference to a specific visit or attributed the deviations into in incorrect (or multiple) visits—such notices were coded separately.

Statistical analyses

Data were analyzed with linear mixed models using the `lmer` function from the `lme4` package (Bates, Maechler, Bolker, & Walker, 2015) and the `summary` and `confint` functions from the `lmerTest` package (Kuznetsova, Brockhoff, & Christensen; 2017) in R (R Core Team; 2016). Models were built with a recall measure as the dependent variable, fixed effects of recall session, visit, and the content and order deviations with all interactions, and random intercepts for participants (Finch, et al., 2014).[32]

All factors were coded using contrasts. For recall session, first (interview, the reference level) was contrasted with second (online session); for content (and order), typical was contrasted with deviation; and for deviation awareness, not aware was contrasted with aware. There were two contrast coding systems for visit: for the primacy effect, Visit 1 (reference) was contrasted with Visit 2 (first contrast), Visit 3 (second contrast), and Visit 4 (third contrast); for the recency effect, Visit 4 (reference) was contrasted with Visit 1 (first contrast), Visit 2 (second contrast), and Visit 3 (third contrast). To be consistent with the analysis procedure we used in previous experiments (Rubínová, et al., in press; Rubínová, et al., 2020), we report fixed factor coefficients from models using primacy effect coding as a baseline and use recency effect coding only to report analyses pertaining to the recency effect (i.e., comparisons of recall between Visit 4 and Visits 2 and 3).

For each model, we first report any main effects of recall session and visit and then any deviation effects and interactions. We mention any interactions between deviations and visit and report results of relevant follow-up analyses at the level of visits (analyses of interaction that did not involve deviations are reported in Appendix D).

Results

Overview

At the general level, almost all participants recalled all three activities (first recall session: 95%, second recall session: 79%). However, recall did not always correspond to what happened during the visits; that is, some participants recalled the

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[32] The inclusion of additional planned random effects of visit and/or recall session was not possible due to a poor fit (the models were overfitting and failed to converge).

activities as occurring in a different order. At the specific level, participants recalled an average of 4.97 (*SD* = 2.75) details per visit in the first and 3.10 (*SD* = 2.60) details per visit in the second recall session. In the first recall session, 53% of details were correctly attributed to visits in which they occurred, 42% were internal intrusions, and 5% were details that never occurred; the corresponding rates from the second recall session were similar: 57%, 40%, and 3% (Table 9 shows descriptive statistics for each measure split by condition and recall session). In the following, we first report exploratory analyses of schematic recall of the visits (i.e., recall of correctly ordered activities) and then turn to planned analyses of correct details and internal intrusions; analyses of new details are reported in Appendix D. Finally, we report participants' mentioning of deviations and any association between deviation awareness and recall.

Schematic recall of visits

Participants recalled fewer correctly ordered activities in the second than in the first recall session (b = -0.39, 95% *CI* [-0.49, -0.29], $t(774)$ = 7.33, p < .001). As is apparent from Figure 16, participants' schematic recall of the visits was disrupted by the presence of any deviation, and these effects largely materialized in the recall of the last visit (where the deviations took place). A follow-up analysis of Visit 4 confirmed negative effects of both deviation and their interaction, which specified that the effect of the content deviation was stronger when order was typical (content: b = -0.56, [-0.84, -0.29], $t(118)$ = 4.03, p < .001; order: b = -0.93, [-1.20, -0.66], $t(118)$ = 6.66, p < .001; interaction: b = 1.48, [0.93, 2.01], $t(118)$ = 5.27, p < .001). The negative effect of the order deviation was additionally present in recall of Visit 3 (we return to this effect in relation to deviation awareness; b = -0.45, [-0.70, -0.20], $t(123)$ = 3.52, p < .001). Finally, the main effect of the order deviation was stronger in the second recall session (b = -0.22, [-0.43, -0.02], $t(774)$ = 2.11, p = .04).

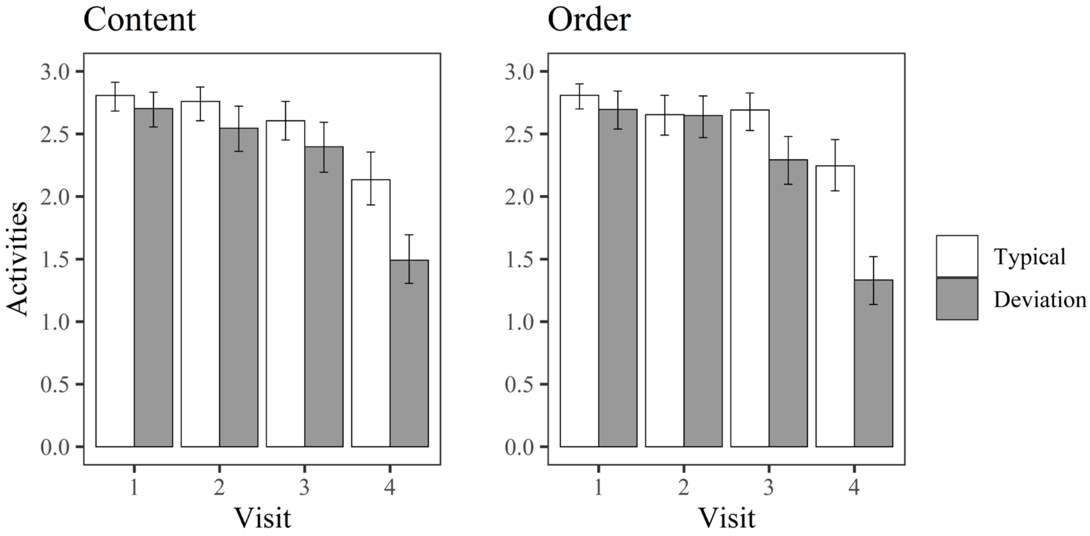

Figure 16. Number of correctly recalled activities across four visits in typical/deviation content and order conditions collapsed across recall sessions. Error bars represent 95% *CI*s of the means.

Table 9
Means and standard deviations of number of correct details, internal intrusions, new details, and activities across visits in two recall sessions split by condition

	Activities in correct order (*Max* = 3)			
Session	Typical both	Deviation content	Deviation order	Deviation both
First	2.98 (0.20)	2.98 (0.20)	2.98 (0.20)	2.98 (0.20)
Second	2.82 (0.58)	2.82 (0.58)	2.82 (0.58)	2.82 (0.58)
	Correct details (*Max* = 12)			
First	2.83 (2.54)	2.83 (2.54)	2.83 (2.54)	2.83 (2.54)
Second	1.91 (1.96)	1.91 (1.96)	1.91 (1.96)	1.91 (1.96)
	Internal intrusions (theoretical *Max* = 12)			
First	1.76 (1.88)	1.76 (1.88)	1.76 (1.88)	1.76 (1.88)
Second	0.90 (1.22)	0.90 (1.22)	0.90 (1.22)	0.90 (1.22)
	New details (theoretical *Max* = 12)			
First	0.27 (0.57)	0.27 (0.57)	0.27 (0.57)	0.27 (0.57)
Second	0.08 (0.35)	0.08 (0.35)	0.08 (0.35)	0.08 (0.35)

Correct details

The analysis of correct details revealed 9% forgetting between the first and the second recall session (results are reported in Table 10). Figure 17 illustrates a strong primacy effect; the recency effect was weaker (see Table 10) and only apparent at interview (see Appendix D). Neither content nor order deviations showed a significant effect (content: $b = -0.03$, 95% *CI* [-0.08, 0.01], $t(129) = 1.36$, $p = .18$; order: $b = 0.01$, [-0.04, 0.06], $t(129) = 0.49$, $p = .63$). There were no significant interactions between the deviations and other factors (highest $t = 1.90$, lowest $p = .06$).[33]

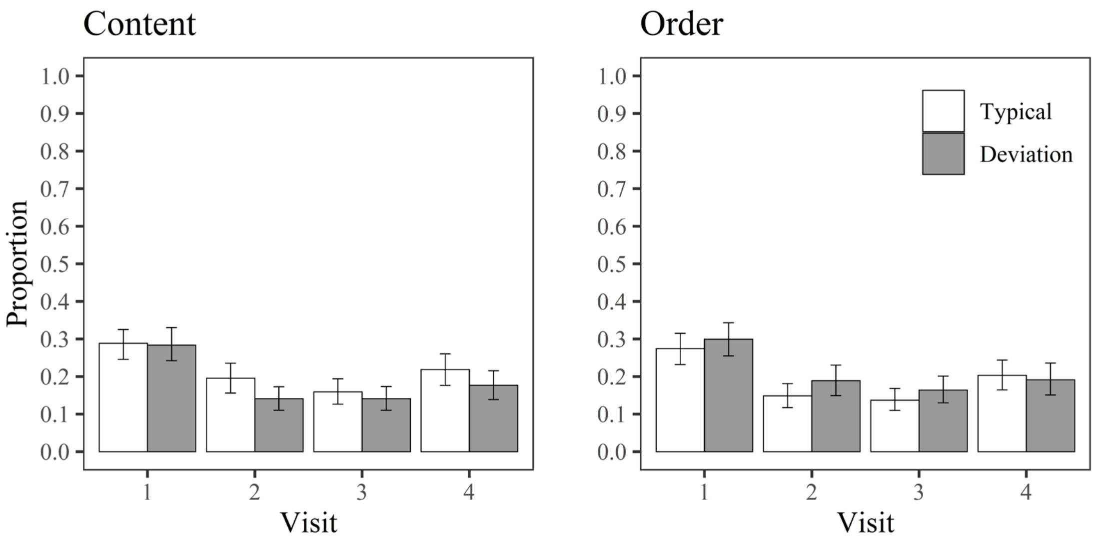

Figure 17. Proportion of correct details across four visits in typical/deviation content and order conditions collapsed across recall session. Error bars represent 95% *CI*s of the means.

Internal intrusions

The analysis of internal intrusions indicated a 6% decrease in internal intrusions between the first and the second recall session (Table 10). Figure 18 illustrates a pattern that is complementary to the recall of correct details: a strong primacy effect and a weaker recency effect (see Table 10 and Appendix D). Again, neither content nor order deviations showed a significant effect (content: $b = 0.02$, 95% *CI* [-0.08, 0.01], $t(130) = 1.49$, $p = .14$; order: $b = 0.001$, [-0.04, 0.06], $t(130) = 0.07$, $p = .94$; Figure 18) and

[33] The strongest of the non-significant effects indicated that in contrast with Visit 1, recall of Visit 2 was slightly lower in deviation content conditions than in typical content conditions (we do not further interpret this pattern).

there were no significant interactions between the deviations and other factors (highest $t = 1.41$, lowest $p = .16$).

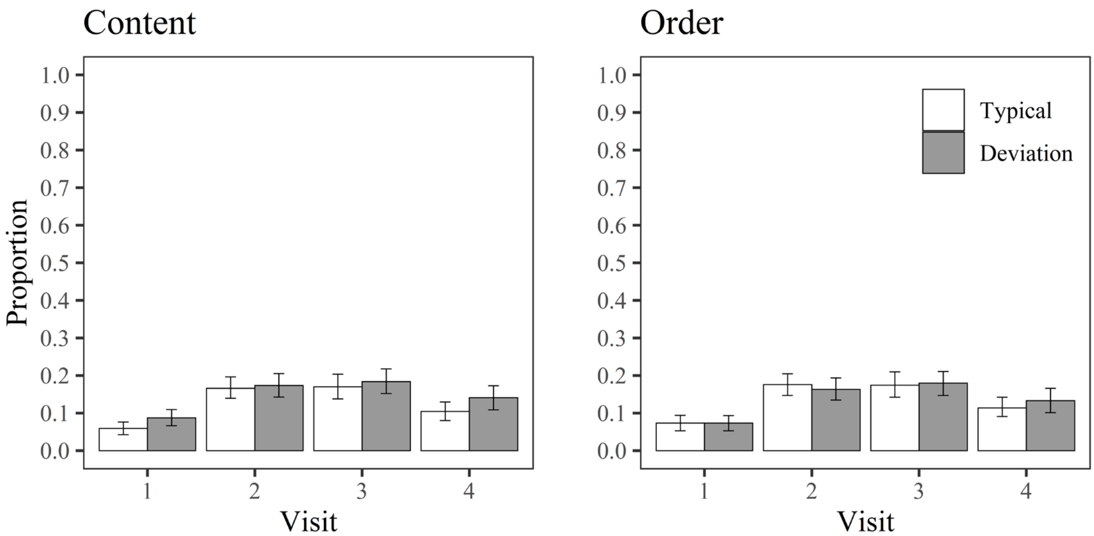

Figure 18. Proportion of internal intrusions across four visits in typical/deviation content and order conditions collapsed across recall session. Error bars represent 95% *CI*s of the means.

Table 10
Session, primacy, and recency effects in the recall of correct details and internal intrusions

	Correct details				Internal intrusions			
Effect	*b*	95% *CI*	*t*	*p*	*b*	95% *CI*	*t*	*p*
Session	-.09	[-.11, -.07]	7.72	< .001	-.06	[-.08, -.05]	6.57	< .001
Primacy								
Visit 1 vs 2	-.11	[-.14, -.08]	7.29	< .001	.09	[.07, .12]	6.90	< .001
Visit 1 vs 3	-.13	[-.16, -.10]	8.52	< .001	.10	[.07, .12]	7.48	< .001
Visit 1 vs 4	-.09	[-.12, -.07]	6.22	< .001	.05	[.02, .07]	3.43	< .001
Recency								
Visit 4 vs 2	-.02	[-.05, .01]	1.06	.287	.05	[.02, .07]	3.47	< .001
Visit 4 vs 3	-.03	[-.06, -.01]	2.30	.022	.05	[.03, .08]	4.05	< .001

Awareness of schema disruption

Spontaneously or when asked about differences across the visits, participants most often mentioned that story versions, products, and devices were different in each visit—that is, participants typically described general variation of details across the visits. From the sample that completed Part 3, only two participants (4% out of 45) in the content deviation conditions, and only six participants (16% out of 38) in the order deviation conditions described that the deviation(s) occurred in Visit 4. In the order deviation conditions, additional seven participants mentioned that the order deviation occurred in Visit 3, and five participants described the deviation without attributing it to a specific visit (in total, 47% of participants in the order deviation conditions mention some kind of order deviation). The deviation recognition measure that was added later during data collection showed similar patterns (see Appendix D).

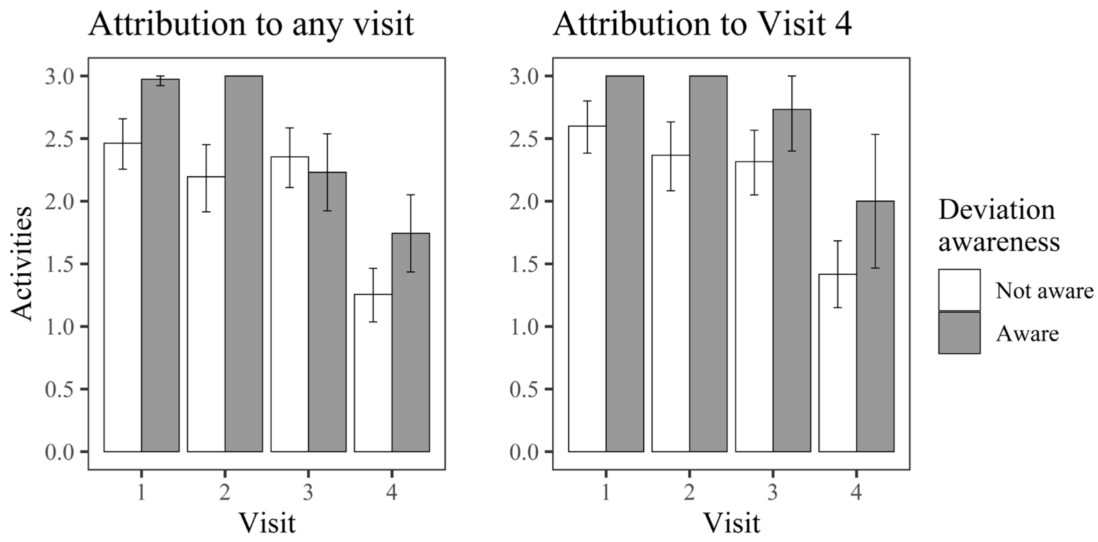

Figure 19. Number of correctly recalled activities across four visits for participants who mentioned the occurrence of a deviation and attributed it to any visit and for participants who (correctly) attributed it to Visit 4 collapsed across deviations recall sessions. Error bars represent 95% *CI*s of the means.

For analyses of the association between deviation awareness and recall in the sub-sample of participants who experienced the deviation(s), we collapsed across all mentions of deviations. The analysis of schematic recall of the visits revealed that participants who reported the occurrence of a deviation recalled more correctly ordered activities than participants who did not report a deviation ($b = 0.42$, 95% *CI* [0.11, 0.73], $t(60) = 2.63$, $p = .01$), and this effect was stronger in the second recall session ($b = 0.45$, [0.15, 0.76], $t(414) = 2.90$, $p = .004$). As illustrated in the left panel of Figure 19, the effect of deviation awareness was not present in the recall of Visit 3 (as shown by a significant contrast with Visit 1: $b = -0.64$, [-1.07, -0.22], $t(409) = 2.91$, $p = .004$). This effect is likely explained by the fact that 18% of participants attributed the order deviation to Visit 3—these participants would more often recall activities in Visit 3 in an *incorrect* order (we observed this effect in schematic recall of Visit 3). The pattern of recall displayed in the right panel of Figure 19, which shows the deviation awareness effect on recall only for participants who attributed the deviation to Visit 4, supports this explanation.[34] The effect of deviation awareness was not significant for correct details or internal intrusions (the results were similar for deviations attributed to any visit or to Visit 4; highest t = 1.25, lowest p = .22; Figure 20).

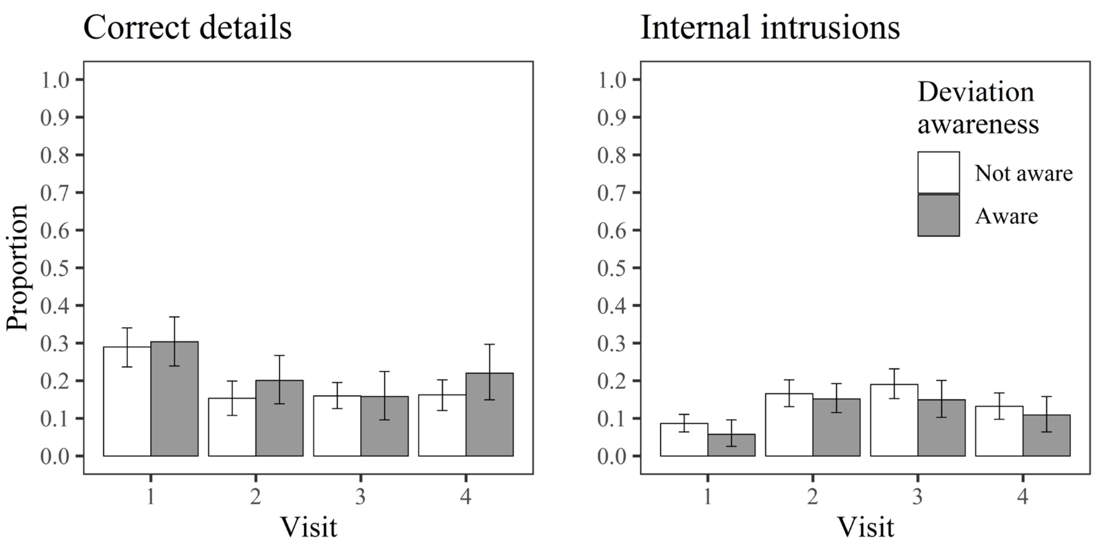

Figure 20. Proportion of correct details and internal intrusions in recall for participants who mentioned the occurrence of any deviation (with or without attribution to any of the visits) collapsed across recall session. Error bars represent 95% *CI*s of the means.

Discussion

The current study investigated how adults remember instances from a complex interactive repeated event and how deviations from content and/or temporal order in one instance may affect recall. At the general level, the results indicated that participants retained an accurate schematic representation of the repeated event if instances varied in a predictable way. When the final instance contained a deviation, its

[34] A parallel graph illustrating the deviation awareness effect on recall for participants who attributed the deviation into Visit 3 (see Figure 32 in Appendix D) shows that such incorrect attribution was associated with *lower* schematic recall of Visit 3.

schematic representation was disrupted, and this happened irrespective of whether content or order deviated. This disruption effect of the deviations, however, did not translate into the specific level of recall of correct details and internal intrusions. In line with our predictions, we found primacy and recency effects: there were more correct details and fewer internal intrusions in recall of the first and the final instance than in the recall of the middle instances, although the primacy effect was greater and more stable across delay than the recency effect. We also found the expected association between remembering that a deviation occurred and better memory for instances from the repeated event, although this effect was again apparent only in schematic recall. We discuss (the lack of) these effects and their implications in turn.

Our findings suggested that deviations may disrupt schematic memory for instances of a repeated event. The negative effect of the content deviation was unexpected and is difficult to interpret, as there is no immediate explanation for why a content deviation—the occurrence of which was almost never reported—would interfere with the schematic memory for that instance. One possibility that would explain at least why the content deviation was not reported is that participants did not interpret the change in the activity as a deviation but merely as a variation within a highly variable set of instances (see also Danby, et al., 2019). For the order deviation, this negative effect was consistent with previous findings (Rubínová, et al., in press; Rubínová, et al., 2020). We observed the disruption in the deviation instance and unexpectedly also in the preceding instance (i.e., Visit 3), although this "spillover" effect can be explained if we consider deviation awareness data. The occurrence of the order deviation was mentioned by approximately a half of participants, but only one third of them correctly attributed the deviation to Visit 4, one third attributed the deviation to Visit 3,[35] and one third made no attribution. Incorrect attribution of the deviation to Visit 3 likely contributed to the disruption of schematic recall of that visit. The association between deviation awareness further supports this interpretation—participants who correctly attributed the deviation(s) into Visit 4 had better schematic memory across all instances from the repeated event.

[35] To our knowledge, this is the first occurrence of *backward telescoping* effect (see Burt, Kemp, & Conway, 2001; Huttenlocher, Hedges, & Prohaska, 1988; Thompson, Skowronski, & Lee, 1988) in repeated event research, although data from Rubínová et al. (in press) include similar indications of this effect. (Note that because the deviation occurred in the final instance, there was no chance to observe *forward telescoping*.)

We found no support for our hypotheses regarding deviation effects in the recall of correct details and internal intrusions, and there seemed to be no translation of effects we observed in the schematic recall into the recall of details. We speculate that this lack of effects might have been caused by the fact that recall of details was cued by activities (and most participants remembered that there were the same three activities in each instance). It is possible that the order of activities did not necessarily interfere with this recall process (i.e., the baseline order as well as the order deviation might have been too simple to impact on the recall of details; contrast with Rubínová, et al., in press).

In line with our predictions, we found a strong and stable primacy effect and a weaker recency effect that disappeared at the second recall session (for consistent results see Powell & Thomson, 1997; see also Dilevski, et al., 2019). The patterns of correct recall and internal intrusions across visits indicated that the first instance and partially also the last instance were somewhat protected from source confusion. The first instance was novel and marked the beginning of the repeated event—these unique attributes likely enabled stronger source links for its details (N. R. Brown, 2016; Lindsay, 2008). The final instance was probably less of a landmark (i.e., it did not mark the beginning of something new), and it might have been more prone to retroactive interference, especially after the first recall due to reconsolidation (e.g., Hupbach, Gomez, Hardt, & Nadel, 2007; Hupbach, Gomez, & Nadel, 2011). At the interview, the recency effect might have been simply caused by the relative recency of the final visit.

Limitations and future directions

The way we applied the content deviation is likely the main limitation of this study. As indicated by the deviation awareness data, what we intended as a deviation was probably not interpreted as a deviation by the participants, consequently limiting the investigation of content deviation effects in this study. A further limitation that may potentially reduce generalizability of our findings into interviewing contexts was in the way we designed the recall sessions. Specifically, we asked participants to recall four visits, which eliminated the possibility that participants would report experiencing fewer or more visits. We know from previous research that children are not very accurate at reporting the frequency of a repeated event (Sharman, Powell, & Roberts, 2011). In adults, though, only one study did not cue participants into recall of specific instances, and the results indicated very few occasions of under- or over-reporting of the number of instances (Kontogianni et al., 2020).

In future research, we believe that to achieve a better understanding of deviation effects in the context of repeated events. If we take into account all sources of content, there are numerous ways in which an event may deviate. Sometimes a similar type of deviation has a positive, sometimes negative, and sometimes no effect, depending on event familiarity, similarity, or type of stimuli (e.g., Connolly, et al., 2016; Danby, et al., 2019; Davidson, 1994; Kontogianni, et al., 2020; Rubínová, et al., in press). Positive and negative deviation effects on recall likely have different underlying mechanisms (e.g., increased processing of details versus schema-level disruptions; MacLean, et al., 2018; Rubínová, et al., 2020), and there is some emerging indication that metacognitive awareness of deviations (i.e., remembering that a deviation occurred), may be key to understanding deviation effects (Rubínová, et al., in press; Rubínová, et al., 2020). However, it seems crucial to reach a better understanding of which characteristics make a detail or a change more likely to be noticed and recognized as a deviation.

Implications

When people recall instances of a repeated event, the vast majority of details they provide are accurate in the broad sense—details that did occur throughout the event (Price, et al., 2016; Woiwod & Connolly, 2017; Woiwod, et al., 2019). The difficulty that emerges in situations that require detail attribution is confusion of details across instances. A growing body of research including the current study shows that the first instance is at least partly immune to such confusion (e.g., Connolly, et al., 2016; MacLean, et al., 2018; Powell & Thomson, 1997; Rubínová, et al., 2020). First instances of repeated events are novel and landmark the beginning of the repeated event, and these unique attributes make them the most suitable target in investigative interviewing where accuracy of attribution of details is crucial.

Instances within repeated events sometimes include unpredictable changes. Such deviation instances may be well remembered (e.g., MacLean, et al., 2018), they may have no effects on recall (e.g., Farrar & Goodman, 1992; Kontogianni, et al., 2020), or they may disrupt recall (e.g., Rubínová, et al., in press; Rubínová, et al., 2020). Importantly, our findings suggested that in a highly variable repeated event similar to real-life experiences, deviations may distort the schematic representation of instances from the repeated event, although people may not remember that a deviation occurred or may attribute the deviation to an instance in which it did not occur.

Acknowledgements

This research was supported by the Society for Applied Research in Memory and Cognition Student Caucus Research Grant. The authors would like to thank Jagoda Mizera, Matthew Seal, Keeley Stevens, Lucia Horváthová, Rafaela Brandao, and Tomáš Rubín for their help with data collection, and Eliška Váchová for her help with coding.

Chapter 5. Discussion

The research presented in this thesis set out to investigate effects associated with adults' memory for typical and exceptional instances of a repeated event. Across five experiments, participants repeatedly encountered stimuli that led to the establishment of a schema in terms of units of *content* presented in a specific *temporal order*. As the complexity of stimuli used in the repeated event paradigm increased, this schema was operationalized as a sequence of word-categories in a list (Experiments 1 and 2, Chapter 2; Experiment 3, Appendix B), actions in a story (Experiment 4, Chapter 3), or activities experienced during a visit (Experiment 5, Chapter 4). Each aspect of the schema, that is, content and order, was then systematically violated by introducing deviations in the final instance using a crossed factorial design. To examine potential deviation effects on memory for the whole repeated event, we measured participants' memory of all instances. Using measures of recall as well as recall organization allowed us to examine the mechanisms underlying deviation effects, schema formation, and any general differences in recall across instances. We additionally collected information about participants' awareness of the deviation(s), which enabled us to see whether content and order deviations differ in how noticeable they are, and to examine any associations between awareness of a deviation and recall. Our hypotheses regarding content deviations were based on previous literature—we expected positive effects on recall (e.g., Connolly, et al., 2016; MacLean, et al., 2018). The investigation of order deviations and awareness of the occurrence of a deviation were novel contributions to the literature.

This discussion presents an overview of findings from Experiments 1 to 5 reported in Chapters 2 to 4 and Appendix B. Theoretical and practical implications of the findings are considered next. Finally, I consider limitations of the current research and outline future research directions.

Summary of findings

This summary is divided into five sections. The first section focuses on indicators of learning and schema formation. The next two sections summarize the main findings pertaining to effects of content and order deviations documented in measures of recall, recall organization, and deviation awareness. The following section focuses on the association between deviation awareness and recall, and the final section provides an overview of primacy and recency effects in the recall of instances of a repeated event.

Learning and schema formation

In Experiments 1, 2 (word-lists), and 4 (unfamiliar stories), we measured immediate recall of each instance shortly after presentation. This measure allowed us to control for the possibility that any potential deviation effects in delayed recall would be caused by differences in learning (we, indeed, did not find any significant effects of deviations in immediate recall). Rehearsal after each instance was additionally intended to facilitate schema formation (see Greve, et al., 2019). In Experiment 3 (word-lists), we explored the possibility that disabling rehearsal of each instance would lead to the formation of a weaker schema, which might consequently limit any schema-deviation effects. Our findings supported this idea (i.e., we found lower rates of sequencing in recall organization, generally lower deviation awareness, and no deviation effects in recall), although we acknowledge that the lack of direct examination of this procedural change as an experimental manipulation does not allow us to draw a strong conclusion.

In Experiment 4, the measure of immediate recall served as a direct indicator of schema formation: as participants learned the schema for the unfamiliar stories, they were able to recall more information from later stories (although the biggest increase occurred between the first and the second story); inversely, as participants learned the new schema, distortions resulting from inadequate pre-existing schemata were less frequent in the recall of later stories (e.g., Brewer & Nakamura, 1984; Cole & Cole, 2000; Schank, 1999). These quantitative and qualitative changes in recall suggest that a new schema was emerging through repeated experience with subsequent stories.

We did not directly examine schema formation in Experiment 5 (marketing-themed visits), but the measure of schematic recall of the instances indicated that participants formed a strong general representation of the repeated event: most participants recalled all three activities that occurred during each instance, and any deviation-related disruptions occurred in the sequencing of these activities in specific instances.

Content deviation effects

Results associated with a content deviation were inconsistent across the experiments, and below I discuss a number of potential factors that might have contributed to such inconsistency. In Experiment 2, we found that more details were remembered from an instance that involved a content deviation, and this effect was partly driven by high recall of the deviation words (consistent with release from proactive interference; Wickens, 1970; and the isolation effect; Cimbalo, et al., 1978; Fabiani & Donchin, 1995; Kelley & Nairne, 2001). This positive effect of the content deviation, moreover, generalized to other instances from the repeated event and was associated with an increase in recall organization according to content clusters. In addition, the majority of participants who experienced the content deviation described its occurrence when we asked them to report any differences across instances a month after the initial session. This effect can be explained by retroactive facilitation—the distinctiveness caused by the content deviation likely engaged participants in contrasting the deviation instance with preceding instances (Connolly, et al., 2016; Higham, et al., 2017; Hintzman, 2011; Putnam, et al., 2017). Such elaboration likely strengthened memory for details of instances as well as the schematic representation of the repeated event.

However, we did not observe a positive effect of a content deviation in Experiments 4 and 5. In fact, we found the opposite effect in Experiment 4: participants' recall of details was lower when an instance contained a content deviation, and this effect was driven by poor memory of the deviation details. In Experiment 5, the content deviation was associated with a distortion of the schematic representation of the deviation instance, although there were no effects in the recall of details.

The discrepancy in the content deviation effects between Experiments 1 and 2 and Experiment 4 may be less surprising if we consider the nature of the materials and their consequences for schema formation. In Experiments 1 and 2, we used simple familiar materials—categorized word-lists—which likely led to a fast schema establishment; the unfamiliar stories used in Experiment 4 required the formation of a more complex schema. With reference to the schema-confirmation-deployment framework (Farrar & Boyer-Pennington, 1999; Farrar & Goodman, 1990, 1992), it is likely that schema formation for the unfamiliar stories was still in the early phase (i.e., schema-confirmation), where information that is consistent with the schema is processed preferentially. Participants, therefore, probably did not have sufficient cognitive capacity to process the deviation details, and low reporting of the occurrence of the content deviation supports this explanation.

The negative effect found in Experiment 5 is more difficult to explain. Very low deviation awareness may suggest that what we intended as a content deviation was not perceived as a schema deviation; one possibility is that participants perceived the change just as an additional variation within a highly variable set of instances rather than a deviation, and perhaps this additional variation interfered with the schematic representation of the instance and contributed to the negative effect.

Order deviation effects

The negative effect of the order deviation was consistent across all experiments. In Experiments 1 and 2, we found that the order deviation disrupted recall of all instances from the repeated event, although the effect was strongest in the deviation instance. This effect was paired with a disruption of recall organization—participants less frequently sequenced their recall according to the order at presentation. In comparison with the content deviation, fewer participants who experienced the order deviation reported its occurrence.

In Experiment 4, the disruptive effect was limited to the recall of idea units of the deviation instance; and was paired with lower sequencing (participants were less able to recall the sequence of themes of the deviation story) and relatively low deviation awareness. In Experiment 5, the order deviation was associated with a disruption of the schematic representation of the visits (as seen in Experiments 1, 2, and 4; Rubínová, et al., in press; Rubínová, et al., 2020). The reason why the effect did not translate into the recall of details in Experiment 5 might be explained by the simplicity of the order aspect of the schema; if participants recalled details according to activities (which they remembered well), it is possible that swapping two of the three activities was too weak of a change to cause any recall disruption. Approximately half of the participants who experienced the order deviation reported its occurrence, although only one third of them attributed the deviation to the deviation instance (one third attributed it to the preceding instance and one third made no attribution).

The disruptive effect of an order deviation is similar to other negative effects of order changes in the literature: disabling subjective recall organization may decrease recall (Postman, 1971), and changing sequential structure within a story decreases comprehension (Ohtsuka & Brewer, 1992; J. M. Mandler & N. Johnson, 1977). We propose a mechanism by which an order deviation may negatively impact on recall of instances of a repeated event. In brief, the order aspect of a schema is implicit, and the order deviation may, therefore, not be explicitly noticed. Memory distortions or disruptions would then result if subsequent recall was guided by an old or undermined schema. Disruption specific for the deviation instance is likely to occur in scenarios where new schema is just emerging and there is insufficient cognitive capacity to process the order deviation (see Farrar & Boyer-Pennington, 1999; Farrar & Goodman, 1990, 1992); disruption across all instances is likely to occur if an established schema is compromised by the added variation of the changed order.

Deviation awareness and recall

Across Experiments 2 to 5, we looked at the association between awareness that a deviation occurred and recall (in these analyses, we did not distinguish between content and order deviations).[36] We found a consistent pattern: participants who reported that a deviation occurred had better memory of all instances from the repeated event than participants who did not report that a deviation occurred. This effect can be explained by more elaborated processing (Craik & Lockhart, 1972) and retroactive facilitation (e.g., Hintzman; see aslo Chapter 2): it is likely that participants who noticed that a deviation occurred contrasted the experience with their memory of the preceding instances and, by doing so, rehearsed their memory. In addition, the fact that these participants noticed the deviation(s) may indicate that they had formed stronger schemata (Danby, et al., 2019; Farrar & Boyer-Pennington, 1999).

Primacy (and recency) effects

Primacy and recency effects were consistent across all experiments as patterns of higher proportion of correct details and lower proportion of internal intrusions in recall of the first and the final instances (see also Connolly, et al., 2016; MacLean, et al., 2018; Powell & Thomson, 1997). Primacy effects were much stronger, and recency effects attenuated (or even disappeared) with delay (see also Dilevski, et al., 2019; Powell & Thomson, 1997). These results indicate that the first instance has a unique

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[36] The two main reasons for collapsing across deviations were: (i) decrease in statistical power as a result of running separate analyses for each deviation (each sample would consist only of participants who experienced the deviation), and (ii) large size differences of the compared groups (e.g., for the content deviation in Experiment 2, 75% of the sample in the “deviation aware” group would be compared with the remaining 25% of the sample who were “not aware” of the deviation).

quality within the repeated event—as a foundational instance, it marks the beginning of the repeated event (N. R. Brown, 2016), and it is also most frequently rehearsed during subsequent experiences (e.g., Hintzman, 2011). Additionally, details of the first instance seem to be protected from interference even during reconsolidation after multiple retrieval attempts; details of the final instance, by contrast, seems to be more prone to such interference during reconsolidation, which may explain why the recency effect decreases with time (and/or as a result of repeated retrieval; e.g., Hupbach, et al., 2007).

Theoretical implications

Implications of this research for theory regarding adults' memory for typical and exceptional instances of a repeated event are discussed below. In brief: (i) effects of content and order deviations seem to be qualitatively different; (ii) deviation effects likely depend on the degree to which a deviation is noticed; and (iii) the level (or strength) of schema formation may modulate deviation effects.

What typically happens during an instance of a repeated event constitutes the content aspect of an event schema; *how* a typical instance proceeds constitutes the *order* aspect of an event schema. If a content deviation occurs in an instance of a repeated event, it is likely to be noticed, especially if the deviation is inconsistent with the schema (Greve, et al., 2019; van Kesteren, et al., 2012) or if it creates consequences for the event (Connolly, et al., 2016; Davidson, 1994; Davidson & Jergovic, 1996; Davidson, et al., 2000; Hudson, 1988; MacLean, et al., 2018). Such explicit change leads to cognitive elaboration of the differences between the deviation instance and other (typical) instances, which leads to a rehearsal that would not occur if the deviation was not present (or it would occur to a lesser degree; Hintzman, 2011). As a consequence, the deviation instance and potentially also other instances from the repeated event would be remembered better. Consistent with Connolly et al. (2016) and MacLean et al. (2018), we found this effect in the recall of correct details in Experiment 2 (and a consistent pattern in Experiment 1). It is likely that this deviation effect is at least partly caused by stronger source memory (although the measure of internal intrusions indicated only small differences; Johnson, et al., 1993; Lindsay, 2008, 2013).

The content deviation effect described above may, however, depend on the level of schema development. Specifically, we should expect a positive effect of content deviation in situations where a relatively strong schema for a repeated event exists. When processing a new instance under such conditions, according to the schema-confirmation-deployment framework (Farrar & Boyer-Pennington, 1999; Farrar & Goodman, 1990, 1992), few cognitive resources are necessary to confirm and deploy the schema, and the remaining cognitive capacity can be used for processing information that deviates from the schema (see also Danby, et al., 2019). In situations where the schema is just emerging or is relatively weak (and plenty of resources are used in the schema-confirmation phase), there may not be enough cognitive capacity to process a deviation. Subsequently, as we saw in Experiment 4, deviation details as well as the occurrence of the deviation would not be remembered well.

The order aspect of an event schema is important for subjective organization of experiences and guiding retrieval (e.g., G. Mandler, 2002, 2011; Postman, 1971; Tulving, 1962), although it may be less explicit (perhaps because sequential changes permit greater variability; J. M. Mandler & N. Johnson, 1977). If an order deviation occurs in an instance of a repeated event, it may not be noticed at all, yet it can have consequences on subsequent recall. In Experiments 1 and 2, the order deviation seemed to undermine the established schema, as was seen in lower recall of details, partial disruption of source memory, and lower sequential organization of all instances of the repeated event, but its occurrence was mentioned much less frequently than the occurrence of the content deviation. The mechanism of the negative effect of the order deviation in Experiment 4 was, however, different. The (low) degree to which the order deviation was noticed was similar to Experiment 2, but the deviation did not seem to undermine the schema of the repeated event—disrupted recall and sequencing was found only in the deviation instance. The patterns of data suggest that participants probably did not manage to encode the new sequence for reasons we described above: the emerging schema was likely in the early stage that did not allow sufficient processing of the deviation order (e.g., Farrar & Goodman, 1990). Retrieval of the deviation instances was subsequently (incorrectly) guided by the old schema.

In summary, this research suggests that deviations may have positive as well as negative effects on recall of the deviation instance as well as other instances from the repeated event. The direction and spread of the effect seem to depend on the degree to which a deviation is noticeable and on the level of schema development. In repeated events for which a schema exists, positive effects should be expected if a noticeable deviation occurs, because this leads to elaborated processing across instances, while negative effects should be expected if a schema deviation occurs that is noticed to a lesser degree. The idea that noticeability of a deviation leads to more elaborated processing is further supported by the positive association between awareness that a deviation occurred and higher recall across instances that was found consistently across all experiments. Content deviations seem to be more likely candidates than order deviations to become noticeable (although the issue of what noticeability means for the person experiencing the instance deserves further investigation). In repeated events for which a schema is just developing, though, deviations may be noticeable to a lesser degree, and they may negatively impact only on recall of the deviation instance due to a greater reliance on the old schema.

A final point should be made regarding the strong and stable primacy effects that we saw consistently throughout all experiments. A wealth of research into the organization of autobiographical memory suggests that memories are organized into clusters that may at least partly consist of repeated events (e.g., Barsalou, 1988; N. R. Brown, 2005; N. R. Brown & Schopflocher, 1998a, 1998b; Burt, Kemp, & Conway, 2003; Kemp, Burt, & Malinen, 2009; Odegard, Lampinen, & Wirth-Beaumont, 2004; Wright & Nunn, 2000). When participants in such studies are asked to recall an event from a specific period, they often provide a description that summarizes a repeated event (e.g., going swimming), or a specific instance of a repeated event (e.g., swimming with a friend; Barsalou, 1988). First instances of repeated events are likely to become landmarks in autobiographical memory (e.g., Berntsen & Rubin, 2004; N. R. Brown, 2016), and they are also often selected as one of the instances of a repeated event that is remembered best (Danby, Brubacher, et al., 2017; Powell & Thomson, 1997). These unique characteristics together with our data suggest that first experiences of repeated events are more likely than other instances to form the content of such autobiographical event clusters.

Practical implications

Implications of this research into the field of applied interviewing are discussed next. In brief: (i) targeting the first instance during an interview may ensure the most complete and accurate report; (ii) deviations within an instance of a repeated event may or may not be recalled depending on how noticeable they were; and (iii) reporting an exceptional instance of a repeated event may be an indicator of good memory.

When adults recall details of instances of a repeated event, they typically recall a mix of correct details and details that originated at other instances (i.e., internal intrusions), confabulations/external intrusions are rare in this context (see also MacLean, et al., 2018; Woiwod, et al., 2019). Such confusions occur more frequently in recall of the middle than the boundary instances, and the first instance seems to be most protected from such errors (see also Connolly, et al., 2016; MacLean, et al., 2018). This pattern suggests that in investigative interviewing settings, targeting the first instance is likely to result in the most detailed and accurate report.

Sometimes, however, recall of a specific instance may be required for investigative purposes, perhaps because it is suspected that an industrial accident or a decline in health condition were a consequence of something unusual that happened during a specific instance of a repeated event (e.g., Kelloway, et al., 2004; MacLean, Brimacombe, & Lindsay, 2013). If such a deviation occurred (e.g., if a worker changed an action within a routine procedure that led to an accident or if a diabetic changed her evening routine and forgot to administer her medication), the likelihood of recall of the deviation would depend on how noticeable it was. If a deviation had a consequence or clearly stood out within the instance, we should expect good recall of the deviation details and the whole instance. Notably, as we consistently saw across all experiments, reporting that a deviation happened in a specific instance may additionally serve as an indicator of a good memory for the whole repeated event. However, another consistent effect indicated that some deviations may happen without the person noticing. In such scenarios, the deviation would not be recalled and recall of the instance might be additionally undermined by a compromised schema or distorted as a result of schema-based inferences (e.g., Bartlett, 1932; Freeman, et al., 1987).

Limitations and future directions

Limitations

I would like to consider four methodological features of the current research that may limit the generalizability of the findings. First, Experiments 1 to 4 used a single session presentation of the stimuli, which is an unlikely scenario in repeated events occurring outside of the laboratory. However, given the simplicity and non-participatory nature of the stimuli used in these experiments, we believe that such a procedure was necessary to limit the simple factor of forgetting that would confound recall measures if word-list or story instances were presented with longer delays. In addition, it seems that the stimuli and their presentation did not affect the overall pattern of recall, which was similar between single-session-presented word-list Experiments 1-3 and Experiment 5, where interactive instances occurred days apart.

Next, the recall format we used across all experiments cued participants into each of the four instances from the repeated event. This would be unlikely to occur in investigative interviewing settings, where the number of instances may not be known. Although we used only simple contextual cues, we eliminated any opportunity for errors potentially stemming from remembering fewer or more instances, which frequently occur in children's reports (Sharman, et al., 2011). We are aware of only one study that did not use contextual cues (Kontogianni, et al., 2020), which however reported few such errors.

An issue related to the generalizability of our findings to interviewing settings is our use of an online recall format to measure delayed recall. In all experiments, the first delayed recall was always measured in the laboratory, but the remaining delayed recall sessions (three sessions in Experiments 1 to 4 and one session in Experiment 5) were administered online. The obvious risks associated with online research are lack of control of the environment, attrition rates, and—in this research specifically—the potential for dishonest behaviour (i.e., if participants inferred that they would be asked to recall the instances in future online sessions, they might have saved their answers). In the current research, attrition rates were relatively low and did not pose difficulties for any analyses. With regards to dishonesty, we gave participants the opportunity to indicate dishonesty (Mazar, Amir, & Ariely, 2008), and in Experiment 4 we checked for any exact matches across delayed recall and excluded such data. Overall, the patterns of data indicated forgetting, as would be expected with such delays, and indicated negligible levels of dishonest behaviour.

The final limitation is specific to the way we implemented the deviations in Experiment 5. We expected the content deviation (i.e., changing the goal and the graphical format of one activity) to be vivid enough for participants to notice. This was probably wrong, as few participants mentioned (or even recognized) the deviation. Consequently, it is likely that we were not able to investigate content deviation effects at all in Experiment 5. As for the order deviation in that experiment, although we saw a disruption effect in the measure of schematic recall of the visits, the lack of translation of the effect into recall of details may indicate that the order deviation was too small to cause any disruption at the level of details (that were likely cued by activities). It seems that we tried to implement deviation changes in an event that was too complex in terms of variable details but too simple in terms of its schema. Overall, this difficulty highlights the need for better theoretical elaboration of the deviation construct in the context of repeated events.

Future directions

Let me conclude this thesis with an outline of three directions for future research. First, if researchers want to understand how exceptional instances of a repeated event are remembered, I believe that a thorough investigation is necessary to gain a better understanding of what is perceived as a deviation from the perspective of the person experiencing the event. A methodological investigation into the perceptions of deviations in a wide variety of stimuli might accomplish this goal. A follow-up investigation of noticeable deviations in the repeated-event paradigm might then inform us whether such deviations are remembered even after a delay, and whether they consistently cause positive deviation effects. Alternative outcomes may point to deviations that are noticed initially but not remembered after a delay and tell us whether such deviations may cause negative effects.

Next, future research that would contribute to investigative interviewing settings should focus on recall consistency. Recalling instances of a repeated event at multiple occasions may pose threats to perceived credibility (as was shown in studies with children; e.g., Price, et al., 2016), mainly due to additional interference resulting from reconsolidation (Hupbach, et al., 2007). To date, there is only one case study that examined consistency of multiple reports of an autobiographical repeated event

(Connolly & Price, 2013), but ground truth in that study was not known. Given that investigative interviewing in repeated events cases would likely require witnesses to provide accounts of several instances of a repeated event, knowing how consistent adults are in the task would be valuable to the applied field (e.g., industrial accidents; Kelloway, et al., 2004; MacLean, et al., 2013).

Finally, I would like to suggest closer collaboration between repeated-event and autobiographical memory researchers. Repeated events provide a basis for the processes that eventually form autobiographical memory (e.g., Barsalou, 1988; N. R. Brown, 2016; Renoult, et al., 2012), but there is not much overlap between the two literatures. Our research suggests that some instances of a repeated event may have unique qualities that would make them candidate instance for representing repeated events in autobiographical memory. To investigate this further, we would need to study long-term memory of experimentally created single and repeated events similar to autobiographical events, preferentially using narrative as well as investigative interviewing techniques. Such research might tell us what components of repeated experiences are maintained in memory after a long delay and how memory for specific instances of a repeated event compares to memory for a unique event; in this way we could learn more about the content and structure of autobiographical memory.

Appendix A. Supplemental materials accompanying Structured word-lists as a model of basic schema: Deviations from content and order in a repeated event paradigm

Experiment 2

Results

The use of schema, correct recall, and source memory across delay

In a final set of analyses, we abstracted from the investigation of deviation effects and explore how schemata are used in guiding recall. At longer delay intervals, memory reconstruction should be based on the schema or 'gist' (e.g., Bartlett, 1932; Brainerd & Reyna, 2002). But what are the relations between schema-based reconstruction, correct recall, and source memory, and (how) do these relations change with delay? One possible scenario—an extreme case of schema-based reconstruction, where little or no instance-specific (source) memory is retained—would be indicated by positive associations of recall organization measures with correct recall as well as internal intrusions. In other words, the schema would help participants recall words, but it would also increase confusion of words across instances. Alternatively, a positive association of recall organization with correct recall paired with weak or no association of recall organization with internal intrusions would indicate that schema aided memory reconstruction and that source memory enabled discrimination between instances.

Our aim in this set of analyses was to explore associations between recall organization measures and (a) correct recall, and (b) internal intrusions, and any time-dependent changes in those associations. We speculated that increasing positive associations between recall organization and both correct recall and internal intrusions across sessions would indicate schema-driven reconstruction paired with little source memory for specific lists. This pattern would indicate an extreme case of schematic recall, where participants cannot discriminate between instances. In contrast, a positive association between organization and correct recall weak or no association between organization and internal intrusions would indicate that the schema aided recall of correct details without compromising source memory.

The respective results are shown in Table 11. Correct details showed strong positive correlations with clustering and weak to moderate positive correlations with sequencing. A test for dependent correlations using the `paired.r` function from the `psych` package in R (Revelle, 2017) revealed that the increase in correlation between Sessions 1 and 4 was not significant for clustering ($t(318) = 1.13$, $p = .26$), but was significant for sequencing ($t(318) = 2.20$, $p = .03$).

Table 11
Correlations between recall organization measures and correct details/internal intrusions

	Correct details		Internal Intrusions	
Measure	*r* [95% *CI*]	*p*	*r* [95% *CI*]	*p*
Clustering				
Session 1	.67 [.60, .72]	< .001	.02 [-.08, .13]	.703
Session 2	.70 [.64, .75]	< .001	.04 [-.07, .15]	.430
Session 3	.71 [.65, .76]	< .001	.16 [.05, .26]	.005
Session 4	.70 [.64, .76]	< .001	.27 [.17, .37]	< .001
Sequencing				
Session 1	.17 [.06, .27]	.003	- .01 [-.12, .10]	.839
Session 2	.39 [.29, .48]	< .001	- .11 [-.22, -.0007]	.049
Session 3	.42 [.33, .51]	< .001	- .05 [-.15, .06]	.419
Session 4	.27 [.17, .37]	< .001	.20 [.10, .31]	< .001

The pattern was different for internal intrusions. In Sessions 1 to 3, the correlations were weak and largely nonsignificant. However, both measures of recall organization showed positive correlations with internal intrusions in Session 4, and the increase in correlation between delayed Sessions 1 and 4 was significant (clustering: $t(318) = 4.00$, $p < .001$; sequencing: $t(318) = 3.34$, $p < .001$).

In summary, the pattern of results suggests that, up to Session 3, the use of schema became more noticeable and helped participants recall correct words. In addition, up to Session 3, participants retained good source memory that helped them discriminate between lists. By Session 4, however, both measures of recall (correct recall as well as internal intrusions) showed positive correlations with recall organization. This pattern is consistent with the idea that memory reconstruction of repeated events is strongly based on schema, and, following long delay intervals, the decreased accessibility of source memory makes it more difficult for participants to discriminate between instances.

Appendix B. Disabling rehearsal in a repeated event paradigm disabled schema establishment and nullified deviation effects

Introduction

In two previous experiments reported in Chapter 2 (Rubínová, et al., 2020), we used a set of word-lists in the repeated event paradigm to investigate effects of deviations of content (i.e., changing one word-category) and order (i.e., changing the temporal order of word-categories). We found that the occurrence of the content deviation was well remembered, the words that deviated were well remembered, and the content deviation was associated with higher recall of words across all instances. The occurrence of the order deviation, on the other hand, was reported less frequently, and the order deviation was associated with lower recall across all instances.

The experimental procedure in those studies (Rubínová, et al., 2020) included, after a brief distraction task, an isolated recall of each word-list. This procedure was motivated by how memory processes work in naturalistic settings where repeated events occur days or weeks apart.[37] In everyday life, people have the opportunity to think back and share their experiences with others, but even without conscious reflection people can be reminded of their experiences by numerous cues present in the environment or conveyed via social interactions (e.g., Hintzman, 2011; Schank, 1999). In contrast with these ecologically valid settings, we used simple stimuli that were presented to participants within a single session. The isolated rehearsal was used to promote encoding and consolidation of individual word-lists (Roediger & Karpicke, 2006a, 2006b), as well as to provide participants with the opportunity to reflect upon the word-lists. Therefore, including an explicit rehearsal necessarily influenced how individual word-lists were remembered.

Rehearsal reduces interference (e.g., Potts & Shanks, 2012; Szpunar, McDermott, & Roediger, 2008). In the repeated event paradigm, this translates into a

[37] Memory consolidation requires time and there is a wealth of research highlighting the role of sleep in this process (e.g., Stickgold, 2005).

reduction of internal intrusions (misattribution errors across the word-lists).[38] In addition, across studies using various types of materials, rehearsal (or testing) is the process through which participants establish the schema (e.g., Greve, et al., 2019; van Kesteren, Beul,, et al., 2013; van Kesteren, Rijpkema, et al., 2013). Therefore, it is possible that disabling rehearsal might lead to insufficient establishment of the schema, which would in turn limit any schema-deviation effects.

The current experiment was a methodological exploration of this point. We were interested to see if active rehearsal played a role in the schema-establishing processes that were reflected in schema-deviation effects, participants' awareness of the deviation(s), and recall organization observed in Rubínová et al. (2020). Specifically, if participants would establish the schema of the word-lists even without active rehearsal, the effects found in Rubínová et al. should replicate. However, if disabling the rehearsal disabled schema formation, we should observe no schema-deviation effects, little deviation awareness, and little schema-consistent recall organization (in contrast with Rubínová, et al., 2020).

Method

The design, materials, procedure, and statistical analyses were the same as in Experiment 2 in Rubínová et al. (2020) with two exceptions. In the experimental procedure, the recall trial one minute after the presentation of each word-list was omitted. In the statistical analyses, we added coding for recency effects. In addition, we report all significant results rather than splitting the results between this manuscript and supplemental materials). The dependent variables were: (i) the proportion of correctly recalled words, (ii) the proportion of internal intrusions (source misattributions), (iii) the awareness the occurrence of any deviation(s), and (iv) recall organization in terms of clustering and sequencing. Data and code for this study are available as OSM under https://tinyurl.com/yb4b3rpf.

Participants

We recruited 102 participants. One participant was excluded due to an indication of dishonesty at the final session. There were 101 participants in the final sample (76 women and 25 men) aged between 18 and 65 years (*M* = 22.25, *SD* = 5.51,

[38] Spacing repeated events over a longer period of time (in contrast with massed presentation) has a similar effect of reducing internal intrusions (Price, et al., 2006).

two participants preferred not to reveal their age); 3 participants did not complete the final recall session. All participants reported that they had normal or corrected-to-normal vision. At the end of the Session 1, participants received a reward of 100 Czech Koruna (approximately £3). Participants were randomly allocated to one of four conditions (typical content and order: n = 25, deviation content and typical order: n = 27, typical content and deviation order: n = 24, deviation content and order: n = 25).

Materials and Procedure

Materials and procedure were the same as in Experiment 2 with one exception: isolated recall one minute after the presentation of each word-list was not administered.

Results

Correct recall

List 4

There was a significant effect of session showing 8% forgetting between sessions (results are reported in Table 12). We found no significant main effects of the deviations (content: b = 0.03, 95% *CI* [-0.08, 0.13], $t(97)$ = 0.49, p = .63; order: b = 0.02, [-0.08, 0.12], $t(97)$ = 0.40, p = .69) and no significant interactions (highest t = 0.78, lowest p = .44). Table 13 displays means and standard deviations across conditions and sessions.

All lists

There was a similar effect of session showing forgetting as delay increased (Table 12). As Figure 21 shows, there was a strong primacy effect and a weaker but also significant recency effect (statistics are reported in Table 12). Effects of the deviations were not significant (content: b = 0.04, 95% *CI* [-0.04, 0.12], $t(97)$ = 0.99, p = .32; order: b = 0.03, [-0.04, 0.11], $t(97)$ = 0.87, p = .39). There was one significant interaction between list and the order deviation indicating that, in contrast with List 1, recall of List 3 was lower in the deviation order conditions than in the typical order conditions (b = -0.09, [-0.16, -0.01], $t(297)$ = 2.22, p = .03). However, as the pattern in Figure 1 and separate analyses of List 1 and List 3 suggest, this effect was driven by the differences between the lists; that is, follow-up analyses of neither list showed a significant effect of the order deviation (List 1: b = 0.07, [-0.02, 0.16], $t(97)$ = 1.58, p = .12; List 3: b = -0.03, [-0.12, 0.07], $t(97)$ = 0.532, p = .60).

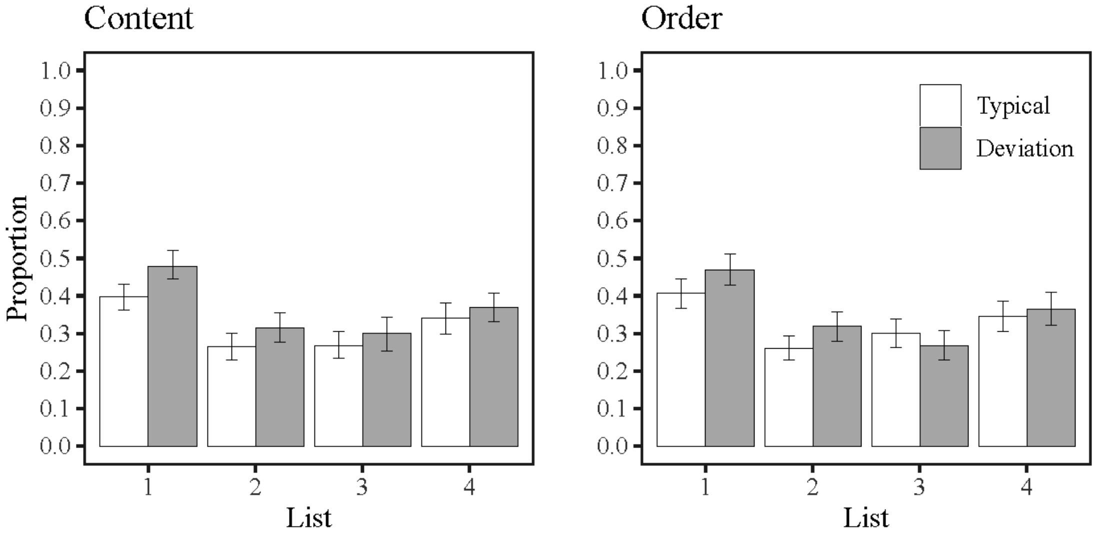

Figure 21. Proportion of correctly recalled words from all lists for content and order deviations collapsed across delay. Error bars represent 95% *CI*s of the means.

Table 12
Session, primacy, and recency effects in the recall of correct details and internal intrusions

	Correct details				Internal intrusions			
Effect	*b*	95% *CI*	*t*	*p*	*b*	95% *CI*	*t*	*p*
Session	-.08	[-.10, -.07]	11.20	< .001	-.02	[-.03, -.004]	2.68	.008
Primacy	-.08	[-.19, -.07]	15.14	< .001	.01	[.005, .02]	3.94	< .001
List 1 vs 2								
List 1 vs 3	-.13	[-.17, -.09]	6.73	< .001	.04	[.01, .07]	2.62	.009
List 1 vs 4	-.14	[-.17, -.10]	7.10	< .001	.08	[.05, .11]	5.52	< .001
Recency	-.07	[-.10, -.03]	3.43	< .001	.04	[.01, .07]	2.80	.006
List 4 vs 2								
List 4 vs 3	-.06	[-.10, -.02]	3.30	.001	-.003	[-.03, .03]	0.17	.861

Internal intrusions

List 4

There was a significant main effect of session showing that there were fewer internal intrusions as delay increased (Table 12). There were no significant effects of deviations (content: b = 0.01, 95% *CI* [-0.04, 0.07], $t(97) = 0.48$, $p = .63$; order: $b = 0.002$, [-0.05, 0.05], $t(97) = 0.08$, $p = .94$) and no significant interactions (highest $t = 0.45$, lowest $p = .65$).

Table 13
Mean proportion of correct recall and internal intrusions

	Correct recall				Internal intrusions			
	List 4							
Session	Typical	Content	Order	Both	Typical	Content	Order	Both
1	.46 (.34)	.53 (.27)	.51 (.35)	.47 (.34)	.13 (.13)	.12 (.20)	.13 (.16)	.15 (.28)
2	.32 (.31)	.37 (.25)	.38 (.31)	.40 (.31)	.12 (.15)	.16 (.17)	.11 (.13)	.15 (.28)
3	.26 (.29)	.36 (.25)	.34 (.32)	.30 (.30)	.09 (.09)	.13 (.17)	.11 (.11)	.11 (.15)
4	.20 (.20)	.24 (.16)	.25 (.25)	.25 (.26)	.09 (.09)	.07 (.11)	.08 (.11)	.09 (.15)
	All lists							
1	.41 (.27)	.51 (.29)	.47 (.32)	.48 (.30)	.09 (.12)	.07 (.12)	.08 (.15)	.07 (.17)
2	.31 (.25)	.38 (.27)	.38 (.29)	.40 (.30)	.16 (.18)	.14 (.17)	.15 (.17)	.11 (.21)
3	.26 (.23)	.31 (.26)	.31 (.30)	.33 (.29)	.14 (.15)	.12 (.16)	.15 (.15)	.10 (.15)
4	.17 (.18)	.21 (.17)	.23 (.25)	.23 (.26)	.12 (.14)	.12 (.16)	.14 (.15)	.09 (.15)

Note. Typical = typical content and order; Content = deviation content and typical order; Order = typical content and deviation order; Both = deviation content and order. Statistics display means and standard deviations.

All lists

The analysis showed that, overall, the number of intrusions slightly increased with delay (Table 12). As Figure 22 shows, there were primacy and recency effects complementing the pattern of correct recall, although the recency effect was significant only in one contrast (Table 12). There were no significant main effects of deviations (content: b = -0.03, 95% CI [-0.06, 0.006], t(97) = 1.61, p = .11; order: b = -0.01, [-0.04, 0.02], t(97) = 0.53, p = .60), and no significant interactions (highest t = 1.96, lowest p = 0.05).[39]

[39] The strongest trend was an interaction between list and the content deviation indicating that in contrast with List 1, there were fewer internal intrusions in List 3 in the content deviation conditions than in the typical content conditions (b = -0.06, [-0.11, 0.0001], t(291) = 1.96, p = .05). A follow-up analysis of List 3 indicated a significant effect of content (b = -0.08, [-0.13, -0.02], t(97) = 2.74, p = .007). We find this effect hard to interpret and treat it as a Type I error.

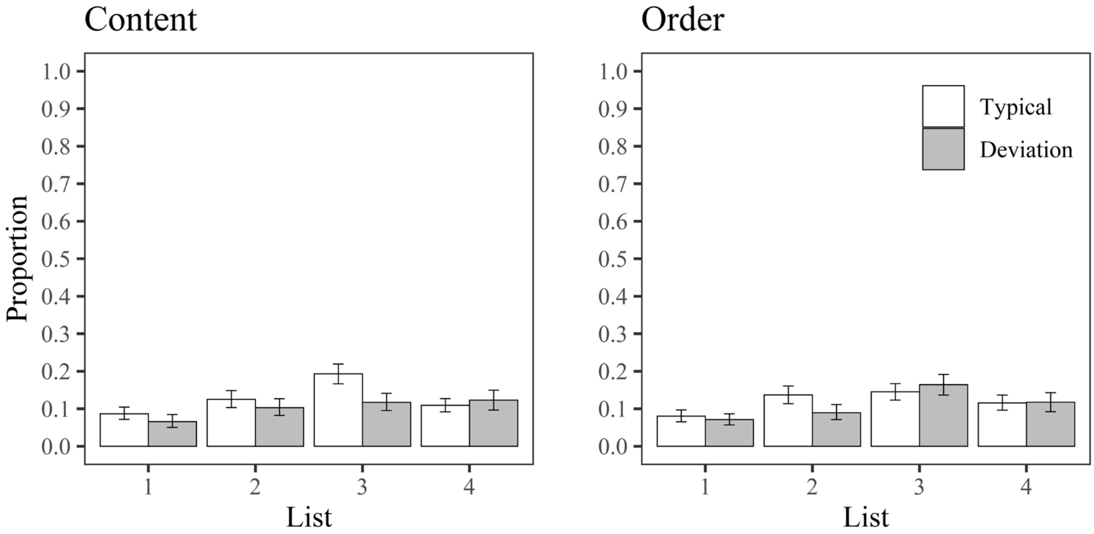

Figure 22. Proportion of internal intrusions in all lists for content and order deviations collapsed across delay. Error bars represent 95% *CI*s of the means.

Awareness of schema (disruption)

After the final recall task, participants were asked to describe the organization of the word-lists and any changes they might have noticed (please note that the following results are based on the 98 participants who completed the final recall task). Fifteen percent of participants mentioned that the word-lists were not organized in any way and 59% of participants mentioned that the word-lists were organized into specific word-categories occurring in a specific sequence; descriptions of the remaining 26% of participants were partially correct or incomplete (e.g., participants mentioned only two categories or said that words from three categories were mixed). In the baseline condition (typical content and typical order), 92% of participants (23 out of 25) correctly reported that there was no change in the organization of the word-lists. In the content deviation condition, 36% of participants (9 out of 25) mentioned changes that reflected the content deviation; in the order deviation condition, 29% of participants (7 out of 24) mentioned changes that reflected the order deviation; in the condition with both content and order deviation, 33% participants (8 out of 24) and 25% of participants (6 out of 24) mentioned changes that reflected the content, respectively the order deviation. In total, there were no significant differences in the frequencies of reporting the content and order deviations, $\chi^2(1, N = 97) = 0.35$, $p = .55$; $OR = 1.43$, 95% CI [0.60, 3.40]).

Analyses of the association between awareness of any deviations and correct recall revealed a main effect of deviation awareness (b = 0.10, 95% *CI* [0.004, 0.20], $t(71)$ = 2.07, p = .04; Figure 23). There was no significant effect of the deviation awareness on internal intrusions (b = 0.02, [-0.02, 0.06], $t(68)$ = 0.91, p = .36).

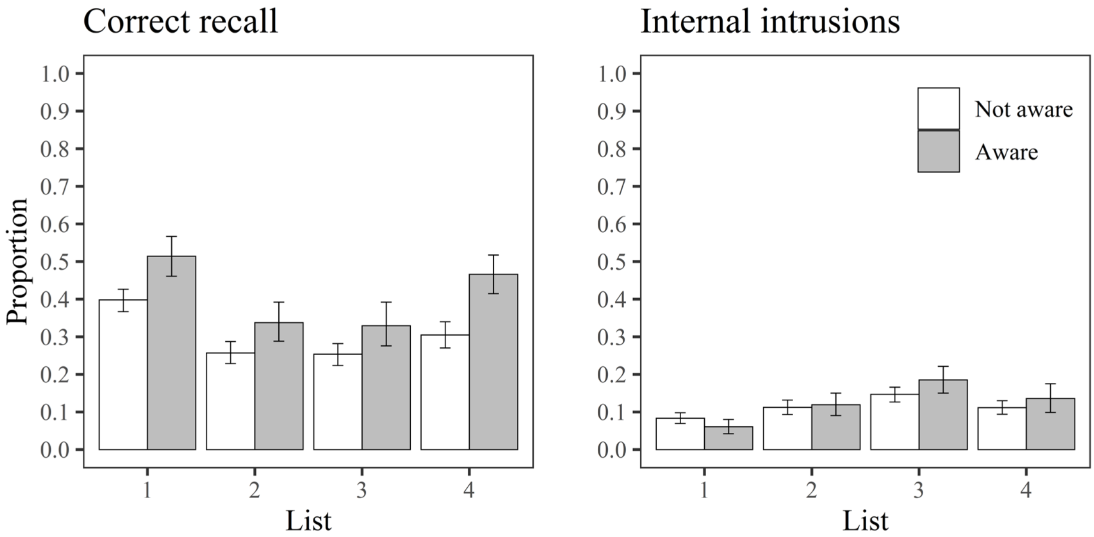

Figure 23. Proportion of correctly recalled words and internal intrusions from all lists for participants who were/were not aware of any deviation (collapsed across delay). Error bars represent 95% *CI*s of the means.

Clustering and sequencing in recall

For the sake of parsimony, we report only analyses of clustering and sequencing pertinent to our hypotheses (i.e., analyses involving the deviations; for other effects, such as primacy and recency effects, interested readers can run the code that is available in OSM, https://tinyurl.com/yb4b3rpf). We found no significant effects of the deviations on clustering (content: b = 0.03, 95% *CI* [-0.18, 0.24], $t(97)$ = 0.26, p = .80; order: b = -0.07, [-0.28, 0.15], $t(97)$ = 0.60, p = .55; Figure 24), and there were no significant interactions between any deviations and other factors (highest t = 1.90, p = .06).[40]

[40] The strongest interaction indicated a trend towards faster decrease in the number of clusters in the content deviation conditions with delay (b = -0.09, [-0.18, 0.003], $t(1196)$ = 1.90, p = .06).

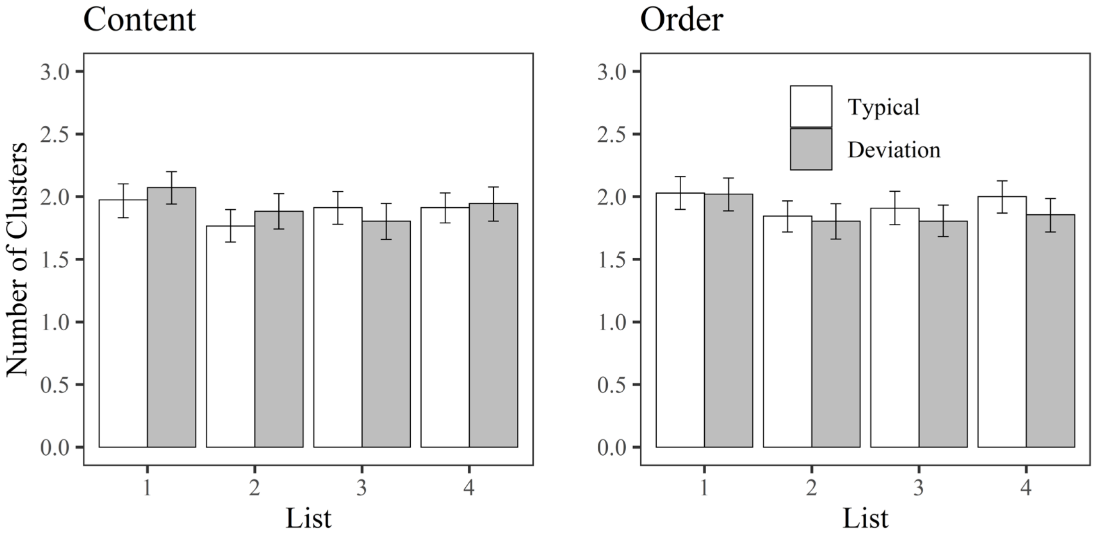

Figure 24. Number of clusters in all lists for content and order deviations (collapsed across delay). Error bars represent 95% *CI*s of the means.

Similarly, there were no significant effects of the deviations on sequencing (content: b = 0.16, 95% *CI* [-0.32, 0.63], t(97) = 0.65, p = .52; order: b = 0.04, [-0.44, 0.52], t(97) = 0.17, p = .87; Figure 25). There was a significant interaction between session and the content deviation indicating that as delay increased, there was fewer correct sequencing in the content deviation conditions than in typical content conditions (b = -0.34, [-0.63, -0.06], t(1196) = 2.35, p = .02). Proportions of correct sequencing across the sessions specified that in Sessions 1 to 3, there was more correct sequencing in the deviation content conditions (38%, 38%, and 33%, respectively) than in the typical content conditions (29%, 30%, and 30%, respectively). In Session 4, there was fewer correct sequencing in the deviation content conditions (18%) than in the typical content conditions (27%). However, we again find this effect hard to interpret and treat it as a Type I error.

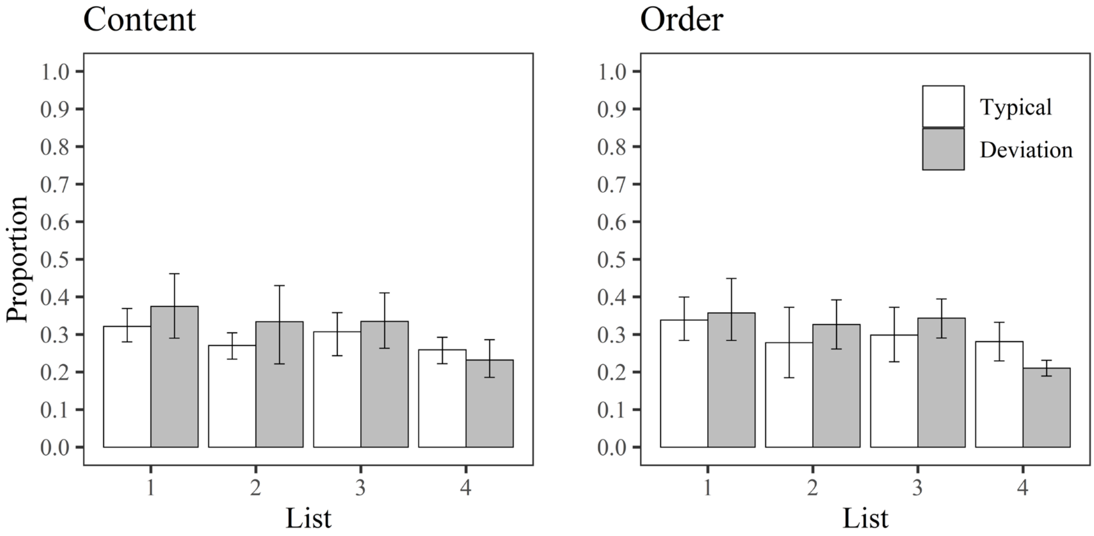

Figure 25. Proportion of correct sequencing in all lists for content and order deviations (collapsed across delay). Error bars represent 95% *CI*s of the means.

Discussion

The results of this experiment can be summarized in six points. First, the deviations had no effect on correct recall of words or internal intrusions. Second, the deviations had no effect on recall organization. Third, for both types of deviations, deviation awareness was relatively low. Fourth, we replicated the effect of awareness: participants who were aware of the deviation(s) recalled more correct words than participants who were not aware of the deviation(s), although this effect was about half the size of that reported in Rubínová et al. (2020). Fifth, recall was generally lower than in Rubínová et al., and although rates of clustering were almost identical, rates of sequencing were almost half the size than in the previous study. Finally, we replicated the general primacy and recency effects (e.g., MacLean, et al., 2018; Powell & Thomson, 1997; Rubínová, et al., 2020).

The first two points suggest that without the active rehearsal of each list there might have been insufficient opportunity for the establishment of the schema for the stimuli, which was supported by lower recall organization in terms of sequencing, lower proportion of participants who correctly reported organization of the word-lists, and lower proportion of participants who reported the occurrence of any deviation(s). In turn, this lack of an established schema likely precluded any deviation effects, which we believe are (at least partly) schematic in nature (see Rubínová, et al., in press;

Rubínová, et al., 2020). We offer this tentative explanation knowing that a proper experimental examination comparing the two methodologies would be necessary, and we leave this as a suggestion for future research.

Appendix C. Supplemental materials accompanying Schema and deviation effects in remembering repeated unfamiliar stories

Method

An example story

“There was a girl named Barbara and a boy named Michael. Mrs Smith, who was Michael’s aunt, went to Barbara’s house to meet with her parents. Mrs Smith told them about Michael’s character, family and education. Two days later, Michael’s parents called on the services of a psychic. He chose March 3rd to send a “saju tanja” to Barbara’s house. On that day, Barbara’s family received a box containing the “saju tanja”, on which the hour, day, month, and year of Michael’s birth were written. There was also a white blouse and a green skirt for Barbara. Barbara’s parents agreed about the day for the ceremony and told Michael’s family. On the day of the ceremony, Michael dressed himself in blue clothes. When Michael and his parents entered Barbara's house, Michael bowed to Barbara's father. Then, Michael gave Barbara's father a wooden goose that he had brought from his house. The company went to a hall. There was a cake, some fruit and a bottle of wine. Michael and Barbara bowed to each other and exchanged three cups of wine. Barbara's father, standing next to a wooden pillar, said: "This is the happiest day of my life".”

Results

In this Supplemental Material, we report significant interactions involving session and story. There were not many of these interactions and they all show very small effects. We did not have any hypotheses for these effects, so we describe them without interpretation. In the final part, we mention results of categorisation of participants’ descriptions of the meaning of the stories that were provided at the end of the final session.

Delayed recall and deviation effects

Idea units

There was a significant two-way interaction between session and story indicating that in time, the decrease in recall of Story 4 was greater than the decrease in recall of Story 1, although the effect was very small and (*b* = -0.02, 95% *CI* [-0.03, -0.003], *t*(1946) = 2.43, *p* = .02; Figure 26).

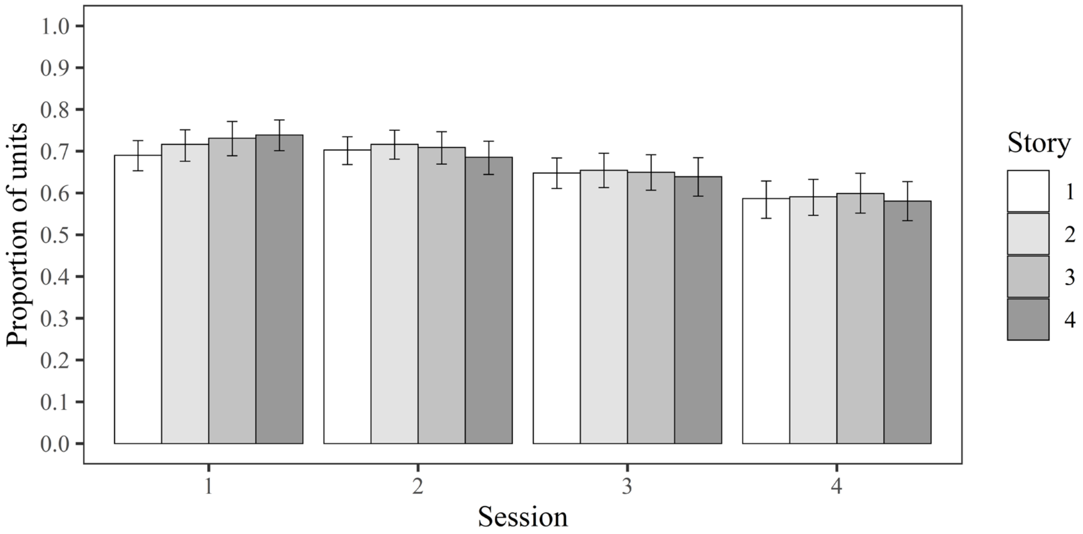

Figure 26. Delayed recall of idea units in Stories 1 to 4 in four delayed sessions collapsed across conditions. Error bars represent 95% *CI*s of the means.

Details

There were significant interactions between session and story in all three contrasts indicating that recall of Stories 2, 3, and 4 decreased faster than recall of Story 1 (Story 1 and 2: *b* = -0.02, 95% *CI* [-0.03, -0.005], *t*(1949) = 2.63, *p* = .009; Story 1 and 3: *b* = -0.02, [-0.04, -0.009], *t*(1949) = 3.22, *p* = .001; Story 1 and 4: *b* = -0.04, [-0.05, -0.02], *t*(1949) = 4.87, *p* < .001; Figure 27).

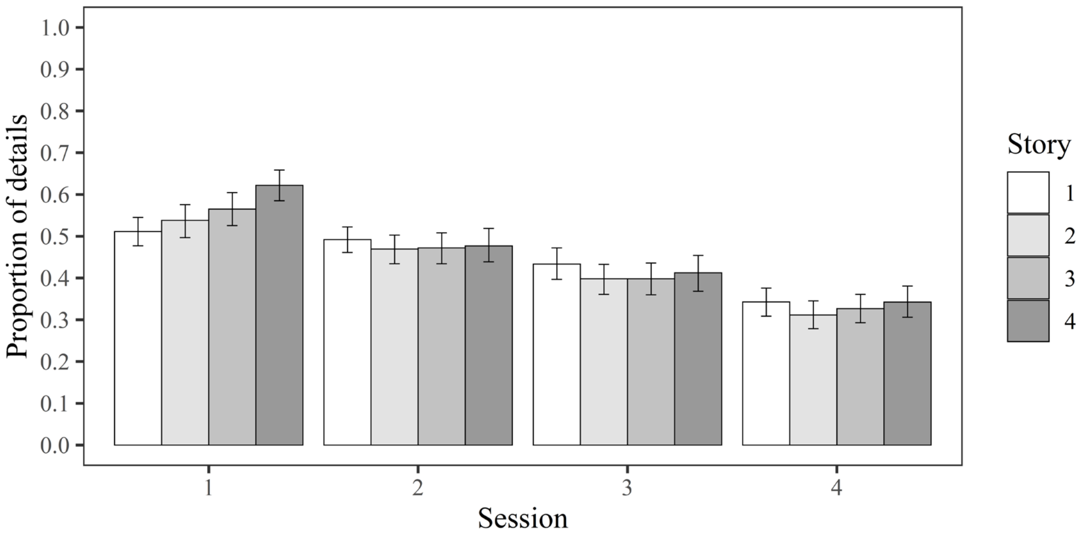

Figure 27. Delayed recall of details in Stories 1 to 4 in four delayed sessions collapsed across conditions. Error bars represent 95% *CI*s of the means.

Internal intrusions

There was a significant interaction between session and story indicating that as delay increased, recall of internal intrusions decreased faster in Story 3 than in Story 1 (b = -0.01, 95% *CI* [-0.02, -0.003], t(1962) = 2.51, p = .01; Figure 28).

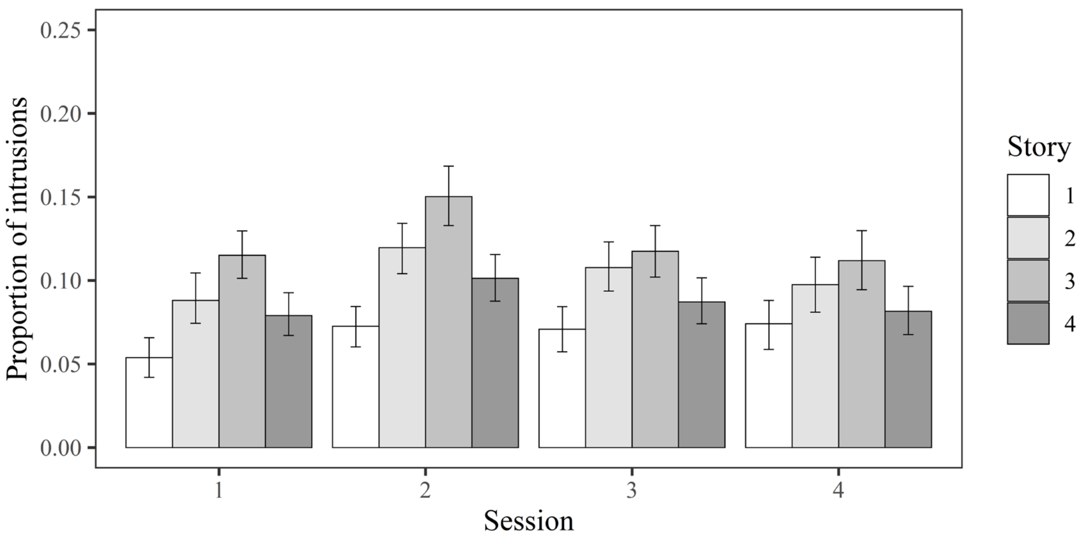

Figure 28. Internal intrusions in delayed recall in four delayed sessions collapsed across conditions. Error bars represent 95% *CI*s of the means.

Distortions

There was a significant two-way interaction between session and story indicating that with increasing delay, there were more distortions in Story 4 than in Story 1 ($b = 0.14$, 95% *CI* [0.03, 0.24], $t(1963) = 2.55$, $p = .01$; Figure 29).

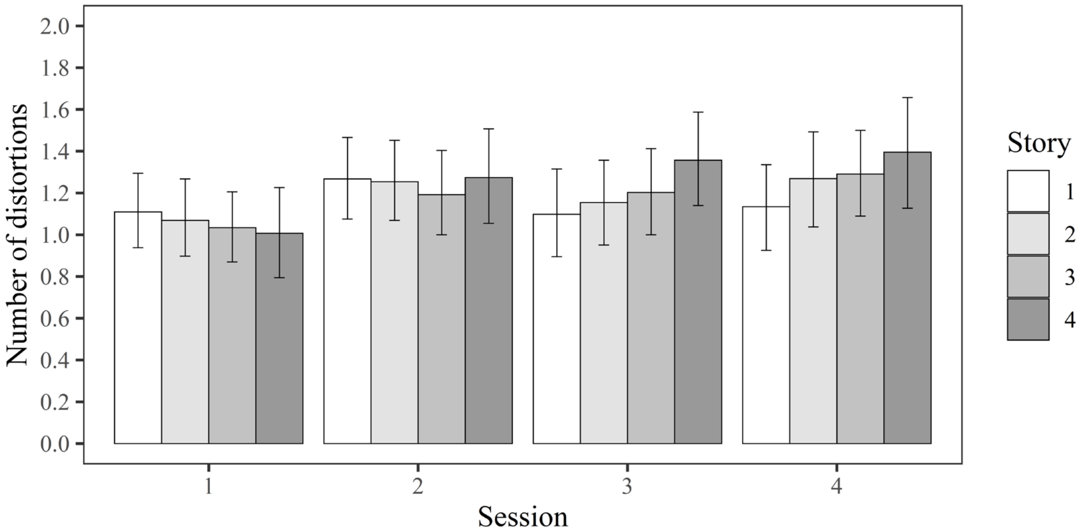

Figure 29. Distortions as a proportion of idea units in four delayed sessions collapsed across conditions. Asterisk indicates measure of distortions excluding deviation details (and parallel details in typical content conditions). Error bars represent 95% *CI*s of the means.

Recall organization

There was a significant three-way interaction between session, story in the contrast between Story 1 and 3 and the order deviation. A follow-up analysis of Story 3 revealed a significant two-way interaction between session and the order deviation, indicating that in time, correct sequencing in the order deviation conditions was higher than correct sequencing in the typical order conditions ($b = 0.06$, 95% *CI* [0.01, 0.10], $t(125) = 2.35$, $p = .02$). Figure 30 specified that the effect was likely driven by the difference in the final recall session.

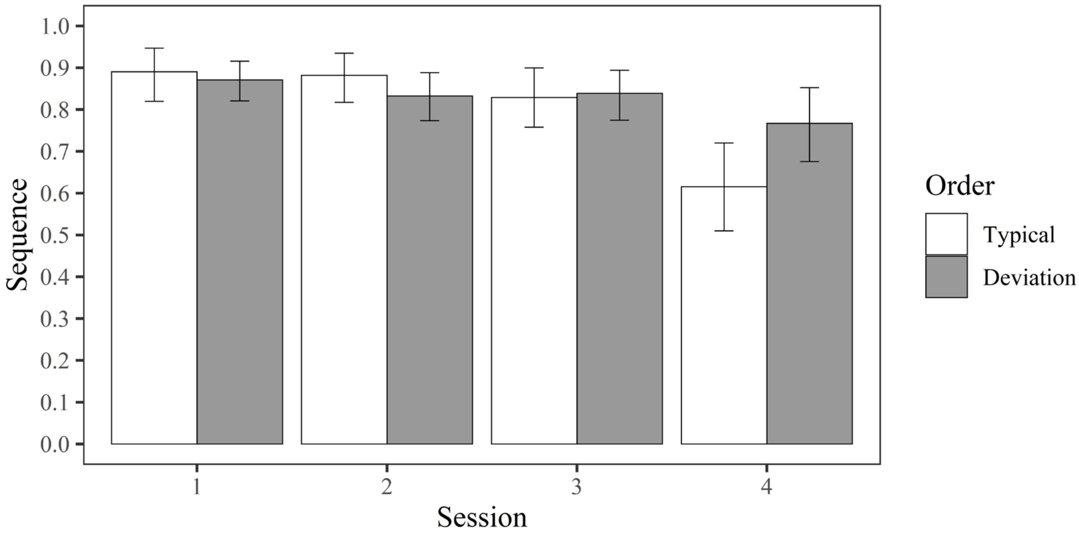

Figure 30. Sequencing in Story 3 in four delayed sessions in typical/deviation order conditions. Error bars represent 95% *CI*s of the means.

Story descriptions

When asked about what the stories might be describing, 94 of the 130 participants who provided an answer (72%) said that the stories described a marriage ceremony, 11 participants (8%) mentioned other events (e.g., “birthday party”), and 25 participants (19%) said that they did not know.

Appendix D. Supplemental materials accompanying Adults' memory for instances from a self-experienced interactive repeated event

Method

Summary of departures from preregistration

There were five departures from our preregistration (see https://tinyurl.com/u6wpfs6): (i) stimulus counterbalancing and (ii) statistical analyses, both resulting from an error in the preregistered plan; (iii) definition of specific details (we added mentioning of a group of products as a specific detail); (iv) exclusion criteria, where we decided to retain all online recall data (including late responses); (v) we do not report preregistered analyses of sequencing due to a ceiling effect (data are available as OSM under https://tinyurl.com/yaswmroh); and (vi) the calculation of inter-rater reliability, where second raters coded only part (rather than all) of the data (see Chapter 4).

Participants and exclusions

Details of sample size calculation

An estimate of the necessary sample size was calculated using GPower (3.1.9.2; Faul, Erdfelder, Lang, & Buchner, 2007) for an *F*-test with four groups and between-subjects factors with two levels, medium effect size ($f = 0.25$), alpha = 0.05, and 80% power.

Timing criteria

We defined timing criteria that, if not met, would lead to data exclusion: Part 1 needed to be completed with a one- to four-day intervals between visits, Part 2 needed to be completed between one and two weeks after the completion of Part 1, and Part 3 needed to be completed four to six weeks after Part 2. As noted, we eventually retained late responses from Part 3 from 7 participants (these responses were late by between 2 to 14 days); all other timing criteria were met.

Exclusions

A total of 191 participants was recruited. One participant dropped out, data from two participants were excluded for failing to meet timing criteria, data from 10 participants were excluded due to errors during the administration of Part 1, and data from 50 participants were excluded due to an initial error in stimulus counterbalancing (where experimental conditions were confounded with sets of stimuli). The final sample consisted of 128 participants.

Measures and coding

Details of the coding process and coding manual

Most manual coding occurred during the data validation phase, where the task was to decide whether recall corresponded to a specific activity or detail. Specifics of coding details for each activity are described below. After data validation, we checked for any occurrences of recall of the same detail in multiple visits—all such occurrences were labelled as "conflict" and subsequently coded as "incorrect" recall. The only exception from this rule was the case of product categories: if a product category was accompanied with a recall of a specific detail (i.e., product brand), that category was coded as specific detail and its other occurrence was coded as "new" (i.e., the participant recalled the product category along with a specific product, but incorrectly recalled the product category as occurring at another visit). As described in Chapter 4, all specific details were then automatically coded as "correct" or "new" details, "internal intrusion", omitted details were coded as "not recalled", and all other labels were coded as "incorrect" recall (note that we only used "correct" and "new" details and "internal intrusions" for statistical analyses).

Game. Game version descriptions or descriptions of the colour of the box that were validated as specific details are listed in Table 14. If recall included several conflicting features (e.g., "Activities in a red box"), it was given a "conflict" label and subsequently scored as "incorrect" recall. Three details of the Game activity—pictures on the dice—were not validated. These details were either automatically coded as "correct" if recall corresponded to the reference sheet, "not recalled" if a detail was omitted, or required further evaluation (sometimes with a reference to recordings of the Game activity). This was due to variability in picture descriptions (e.g., the reference sheet contained: "big and small people" and "sac bag", but the participant recalled: "big man and small man" and "sack"; these details were manually coded as "correct"). Recall of other versions or pictures that could not be recognized as specific details were coded as "new".

Table 14
Descriptions and colours that were validated as specific details for Game version

Version	Description including	Box colour
Original	Original, basic, normal, regular	Red or orange
Voyages	Voyages, travel, locations, adventures	Green
Fantasia	Fantasia, fantasy, myths, fairy tales	Pink, purple, violet
Actions	Actions, activity, active	Blue

Products. To be validated as specific detail, recall needed to include the brand name of the product. The exception from this rule was "Terry's chocolate orange", where recall of "chocolate orange" was validated as specific detail, "Vita coco coconut water", where recall of "Vita coco" or "coconut water" was validated as specific detail, and "Sure", where "Rexona" was also validated as specific detail (this was because the brand name outside of the UK is different although the design of the product is the same). Recall that included descriptions of the product (e.g., "a shower gel in a green bottle") were labelled as "vague" and subsequently coded as "incorrect". Recall that mentioned other brands were coded as "new".

Device. Any device descriptions that could be recognized as one of the four devices (vertical mouse, white marker, laser pointer, and decorative scissors) were coded as specific details. Descriptions of other devices (e.g., "web camera") were coded as "new". One issue that occurred during validation was the description of a "pen", which sometimes referred to the laser pointer and sometimes to the white marker. In such situations, we looked at other details recalled for that activity to clarify this issue. Validating recall of the three tasks associated with each device was relatively straightforward for the vertical mouse (participants drew a "house", a "car", and a "tree" on Paint) and the white marker (participants drew an "exclamation mark", a "dollar sign", and a "tick sign"). For the decorative scissors (participants cut out a "card", a "star", and a "heart"), we validated descriptions of cutting out a "rectangle" or "square" as "card". For the laser pointer (participants "circled around a monkey", "crossed out a hen", and "underlined a horse"), we validated descriptions of actions only, pictures only, or both actions and pictures as specific details, unless they were recalled in conflicting combinations (e.g., "I was asked to underline a picture of a monkey"), in which case they were labelled as "conflict" and coded as "incorrect" recall.

Comparison of written and spoken reports from Part 2

Table 15 displays means and standard deviations for the numbers of recalled activities, details, internal intrusions, and new details in the written and spoken phases of Part 2 interview.

Table 15
Comparison of numbers of reported activities, details, internal intrusions, and new details between written and spoken report phases in Part 2

Report phase	Activities	Details	Intrusions	New details
Written	2.40 (0.99)	2.48 (2.40)	1.77 (1.93)	0.19 (0.48)
Spoken	2.54 (0.90)	2.71 (2.51)	1.88 (1.99)	0.24 (0.52)

Deviation awareness

Examples of descriptions coded as "aware": "[Visit 3] survey – agree/disagree; [Visit 4] rated it – on scale with smiley faces" (content deviation attributed to Visit 4), "I think the order in the fourth visit was different" (order deviation attributed to Visit 4).

Results

Correct details

Figure 31 illustrates additional interactions between visit and session. In the model using the primacy effect coding, this interaction indicated that the difference between recall of details from Visit 1 and Visit 3 was greater in the first than in the second session (b = 0.07, 95% CI [0.01, 0.13], $t(694) = 2.24$, $p = .03$). In the model using the recency effect coding, these interactions indicated that the recency effect (i.e., higher recall of details from Visit 4 than from Visits 2 and 3) was only present at interview (Visit 4 vs 2: b = 0.11, [0.05, 0.17], $t(694) = 3.55$, $p < .001$; Visit 4 vs 3: b = 0.12, [0.06, 0.18], $t(694) = 3.85$, $p < .001$).

Internal intrusions

Figure 31 illustrates additional interactions between visit and session. In the model using primacy coding, this interaction specified that the primacy effect (i.e., higher recall of details from Visit 1 than from Visits 2 and 3) were greater in the first than in the second session (Visit 1 vs 2: b = -0.06, 95% *CI* [-0.11, -0.01], $t(697) = 2.15$, $p = .03$; Visit 1 vs 3: b = -0.06, [-0.11, -0.01], $t(697) = 2.41$, $p = .02$).

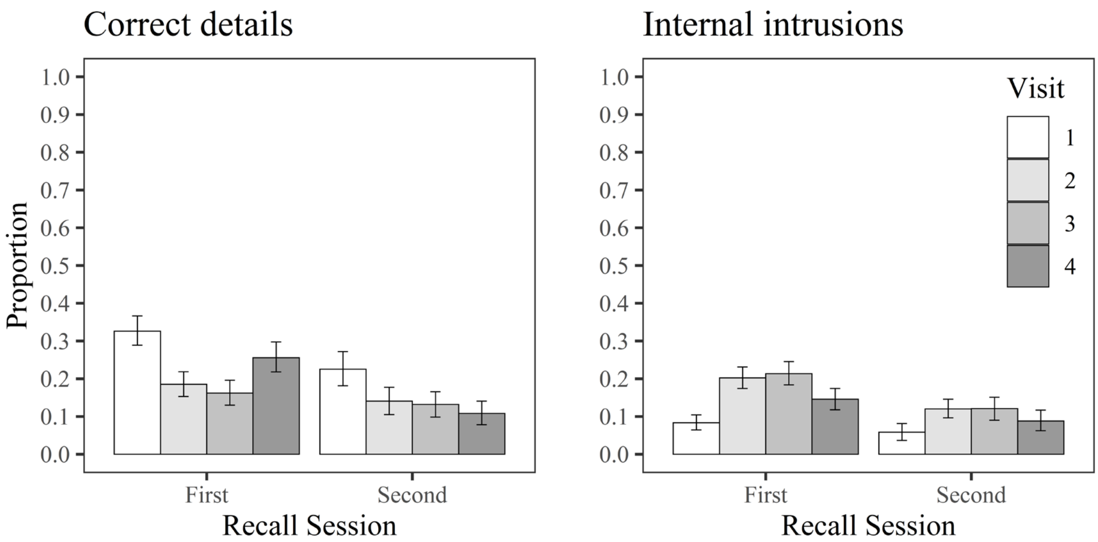

Figure 31. Proportion of correct details and internal intrusions across four visits in the interview and online recall sessions collapsed across deviations. Error bars represent 95% *CI*s of the means.

New details

Participants recalled between 0 and 3 new details that were typically same-category confabulations. Due to such low frequency, we decided to convert new details into a binomial measure and conduct exploratory chi-square analyses. Collapsed across visits and recall session, we found more frequent reporting new details in the deviation content than in the typical content conditions (18% vs 13%, respectively), but the difference was not significant (content: χ^2(N = 848, 1) = 3.84, $p = .05$; a parallel analysis for order: χ^2(N = 848, 1) = 0.14, $p = .71$).

Awareness of schema disruption

Figure 32 illustrates the pattern of recall of activities for participants who were aware that a deviation occurred but incorrectly attributed the deviation into Visit 3 (left panel) or made no visit attribution (right panel).

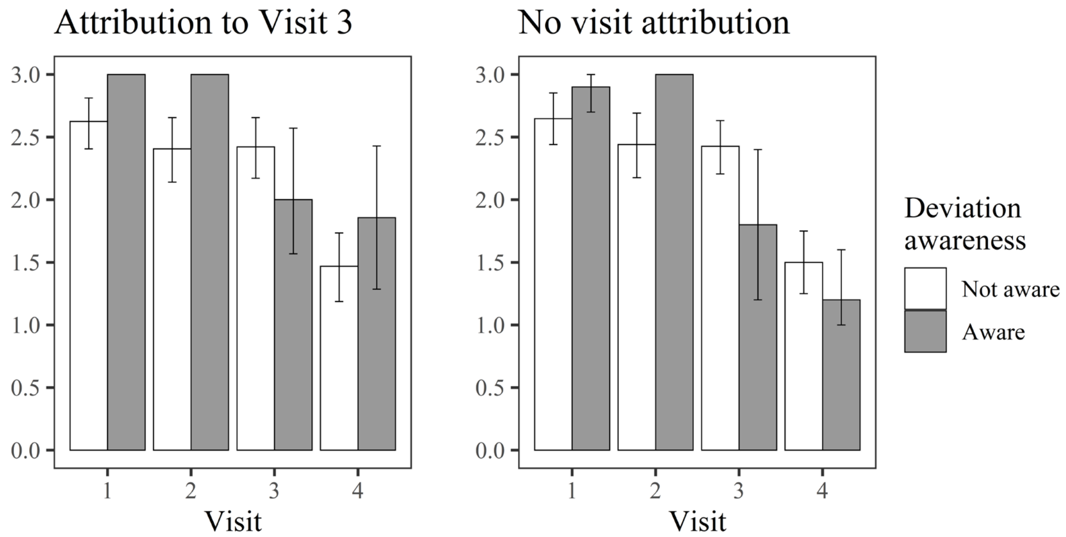

Figure 32. Number of correctly recalled activities across four visits for participants who mentioned the occurrence of a deviation and (incorrectly) attributed it to Visit 3 or who made no visit attribution collapsed across deviations recall sessions. Error bars represent 95% *CI*s of the means.

Recognition measure

Due to a late inclusion of the deviation recognition questions, we have data from a limited number of participants (although the patterns are consistent with deviation awareness that we coded from participants' descriptions of differences across the visits reported in Chapter 4). Two out of 19 participants in the content deviation conditions indicated that they remembered that the content deviation occurred: one attributed it to Visit 3 and one made no visit attribution. Eight out of 14 participants in the order deviation conditions indicated they remembered that the order deviation occurred: three attributed it to Visit 4, four attributed it to Visit 3, and one made no visit attribution.

Appendix E. Ethics

Faculty of Science
University of Portsmouth
St Michael's Building
White Swan Road
PORTSMOUTH
PO1 2DT

Date 26/02/14

FAVOURABLE OPINION

Protocol Title: **Remembering repeated events**

Dear Eva,

Thank you for submitting your protocol for ethical review.

Your protocol has been reviewed and I am pleased to inform you that your application has been given a favourable opinion by the Science Faculty Ethics Committee. Thus, no further action is required on your part.
Please notify us in the future of any substantial amendments that may be required and send us a final study report.

Good luck with the study.

Best wishes,

Dr. Juliane Kaminski
(Dept) Science Faculty Ethics Committee

CC -
Dr Chris Markham – Chair of SFEC
Sci.fac@port.ac.uk
Holly Shawyer – Faculty Administrator

Faculty of Science
University of Portsmouth
St Michael's Building
White Swan Road
PORTSMOUTH
PO1 2DT

Date 6/05/14

FAVOURABLE OPINION

Protocol Title: **Remembering repeated events (remembering stories)**

Dear Eva,

Thank you for submitting your amended protocol for ethical review.

I am pleased to inform you that your application has been given a favourable opinion by the Science Faculty Ethics Committee. Thus, no further action is required on your part.

Please notify us in the future of any substantial amendments that may be required and send us a final study report.

Good luck with the study.

Best wishes,

Dr. Juliane Kaminski
(Dept) Science Faculty Ethics Committee

CC -
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Holly Shawyer – Faculty Administrator

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13 February 2018

Eva Rubinova
Department of Psychology
University of Portsmouth

Eva.Rubinova@port.ac.uk

FAVOURABLE ETHICAL OPINION

Study Title: Which products do you prefer? Investigating memory for a series of marketing-themed visits

Reference Number: SFEC 2018-014

Date Submitted: 25 January 2018

Thank you for submitting your proposal to the Science Faculty Ethics Committee (SFEC) for ethical review in accordance with current procedures.

I am pleased to inform you that SFEC was content to grant a favourable ethical opinion of the above research on the basis described in the submitted documents listed at Annex A, and subject to standard general conditions (*See Annex B)*.

Please note that the favourable opinion of SFEC does not grant permission or approval to undertake the research. Management permission or approval must be obtained from any host organisation, including the University of Portsmouth or supervisor, prior to the start of the study.

Wishing you every success in your research.

Dr Paul Morris
Vice Chair, Science Faculty Ethics Committee

Appendix F. UPR16 Form

FORM UPR16

Research Ethics Review Checklist

Please include this completed form as an appendix to your thesis (see the Research Degrees Operational Handbook for more information

UNIVERSITY OF PORTSMOUTH

Postgraduate Research Student (PGRS) Information			**Student ID:**	725609	
PGRS Name:	Eva Rubinova				
Department:	Psychology	**First Supervisor:**	Dr Hartmut Blank		
Start Date: (or progression date for Prof Doc students)		October 2014			
Study Mode and Route:	Part-time ☒	Full-time ☐	MPhil ☐	PhD ☒	MD ☐ Professional Doctorate ☐

Title of Thesis:	Schema and deviation effects in adult's memory for repeated events
Thesis Word Count: (excluding ancillary data)	32 210

If you are unsure about any of the following, please contact the local representative on your Faculty Ethics Committee for advice. Please note that it is your responsibility to follow the University's Ethics Policy and any relevant University, academic or professional guidelines in the conduct of your study

Although the Ethics Committee may have given your study a favourable opinion, the final responsibility for the ethical conduct of this work lies with the researcher(s).

UKRIO Finished Research Checklist:
(If you would like to know more about the checklist, please see your Faculty or Departmental Ethics Committee rep or see the online version of the full checklist at: http://www.ukrio.org/what-we-do/code-of-practice-for-research/)

a) Have all of your research and findings been reported accurately, honestly and within a reasonable time frame?	YES NO	☒ ☐
b) Have all contributions to knowledge been acknowledged?	YES NO	☒ ☐
c) Have you complied with all agreements relating to intellectual property, publication and authorship?	YES NO	☒ ☐
d) Has your research data been retained in a secure and accessible form and will it remain so for the required duration?	YES NO	☒ ☐
e) Does your research comply with all legal, ethical, and contractual requirements?	YES NO	☒ ☐

Candidate Statement:	
I have considered the ethical dimensions of the above named research project, and have successfully obtained the necessary ethical approval(s)	
Ethical review number(s) from Faculty Ethics Committee (or from NRES/SCREC):	SFEC 2014-010 SFEC 2018-014
If you have *not* submitted your work for ethical review, and/or you have answered 'No' to one or more of questions a) to e), please explain below why this is so:	
NA	
Signed *(PGRS)*:	**Date:** 11 May 2020

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