Structured word-lists as a model of basic schemata: Deviations from content and order in a repeated event paradigm

Eva Rubínová[a], Hartmut Blank[b], James Ost[c], and Ryan J. Fitzgerald[d]

University of Portsmouth, Department of Psychology, University of Portsmouth, King Henry Building, King Henry I Street, PO1 2DY, Portsmouth, Hampshire, United Kingdom

E-mail:

[a]eva.rubinova@port.ac.uk

[b]hartmut.blank@port.ac.uk

[c]james.ost@port.ac.uk

[d]ryan.fitzgerald@port.ac.uk

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Author Note

Correspondence concerning this article should be addressed to Eva Rubínová, Department of Psychology, University of Portsmouth, King Henry Building, King Henry I Street, PO1 2DY, Portsmouth, Hampshire, United Kingdom.

E-mail: eva.rubinova@gmail.com

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. The cognitive processes underlying memory for typical and exceptional instances of repeated events are discussed.

Key words: schema, schema-deviation, repeated events, recall organization, metacognition, source memory

Structured word-lists as a model of basic schema: Deviations from content and order in a repeated event paradigm

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, W.F. Brewer, & Mooney, 1992; Ghosh & Gilboa, 2013; Nørby, 2015; Renoult, Davidson, Palombo, Moscovitch, & Levine, 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, Ruiter, & Fernández, 2013), paired associates (van Kesteren et al., 2013), and familiar and unfamiliar stories or videos (Bartlett, 1932; Davidson et al., 2000; Tuckey & N. Brewer, 2003). 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., W. F. Brewer & Nakamura, 1984). Even when specific details are not available in memory, schematic (i.e., 'gist') information is often readily available (Brainerd & Reyna, 2002; W. F. 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, Glisic, Roberts, & Powell, 2011), or 'absorbed into' the schema (e.g., Bartlett, 1932; W. F. Brewer & Treyens, 1981), resulting in limited ability to distinguish between the source of origin (Johnson, Hashtroudi, & Lindsay, 1993). If one instance deviates from the schema, however, the event can become distinctive and the details can become more memorable (e.g., W. F. Brewer, 2000; Connolly, Gordon, Woiwod, & Price, 2016; Nakamura, Graesser, Zimmerman, & Riha, 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, Malmstrom, Burdenand, and Luo (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 N. Brewer (2003) 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, Coburn, Chong, and Connolly (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 & N. Brewer, 2003).

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	Baseline	Content Deviation	Order Deviation	Content & Order 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 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.[1] The experiment was programmed using OpenSesame (Mathôt, Schreij, & Theeuwes, 2012) and self-administered.

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

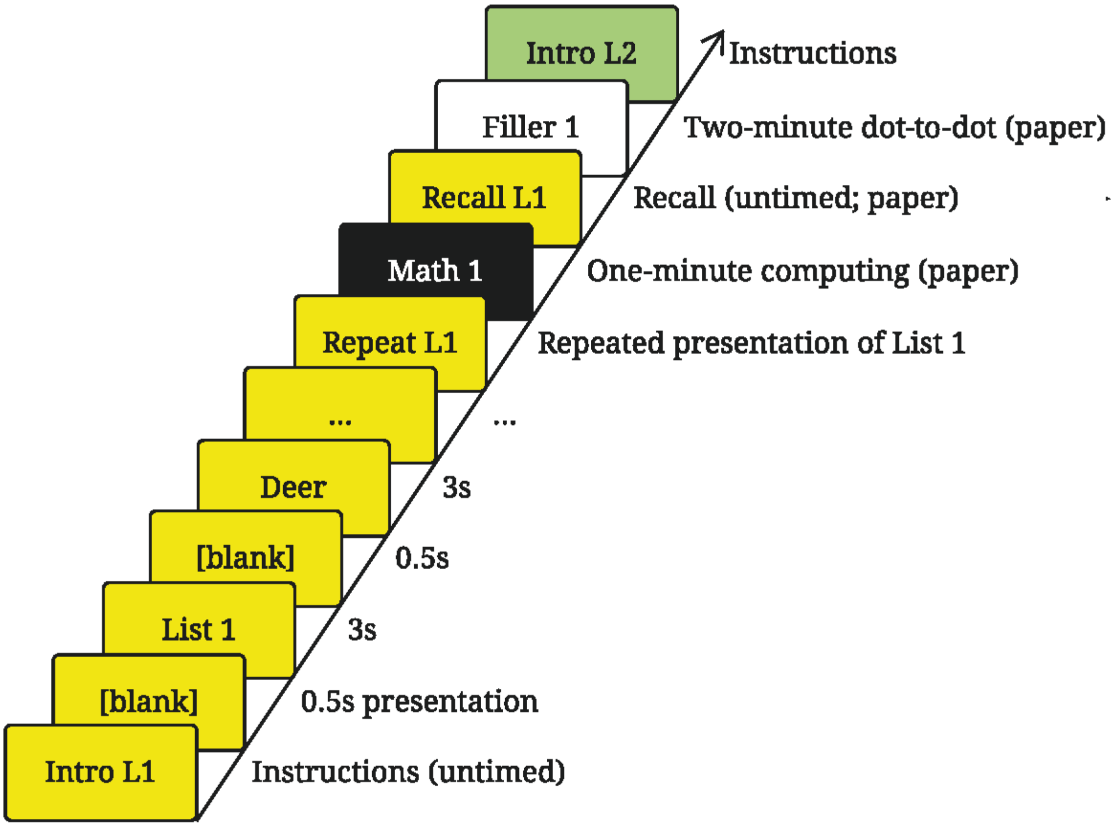

Figure 1. A flowchart of the learning phase of Session 1.

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 an

ANOVA context); 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.

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 with all analyses and the data set can be found in the Supplemental Materials.

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 Supplemental Materials. We present regression coefficients along with 95% confidence intervals (CI) to show the range of plausible values (Cumming, 2012, 2014).

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	Baseline	Content	Order	Both	Baseline	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. 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.

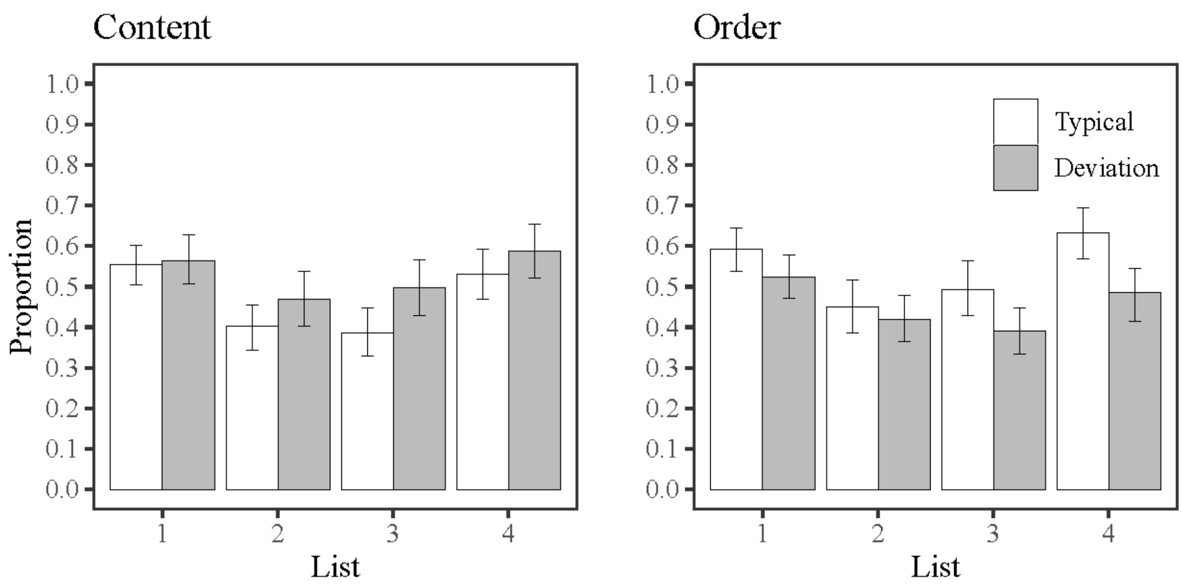

Figure 2. Proportion of correctly recalled words from all lists for content and order deviations (collapsed across delay). Error bars represent 95% CI of the mean.

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).[2] 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

[2] 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.

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, 95% CI [-0.02, 0.08], $t(92) = 1.18$, $p = .24$).

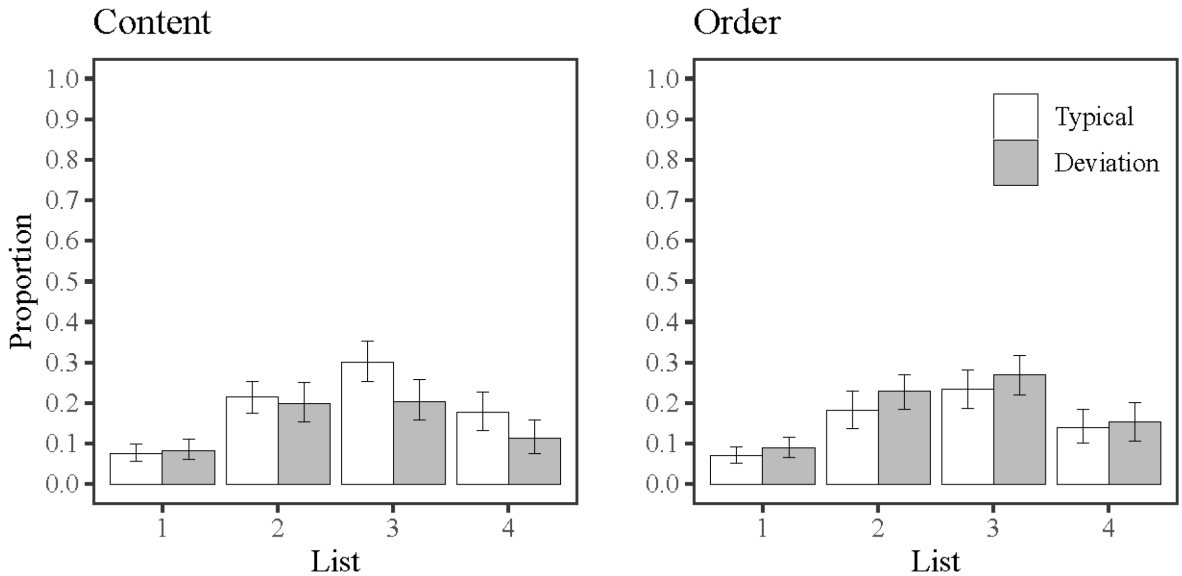

Figure 3. Proportion of internal intrusions in all lists for content and order deviations (collapsed across delay). Error bars represent 95% CI of the mean.

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.[3] 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

[3] 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.

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).

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.[4] 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 within participants and random slopes for session across list nested within participants[5] (Finch, Bolin, & Kelley, 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 all analyses and the data set can be found in the Supplemental Materials.

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 the Supplemental Materials.

Learning. As in Experiment 1, there were no significant effects of deviations on initial reproduction of List 4 (content: $b = 0.02$, [-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.

[4] 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.

[5] 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 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 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).

Correct recall: 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).

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).

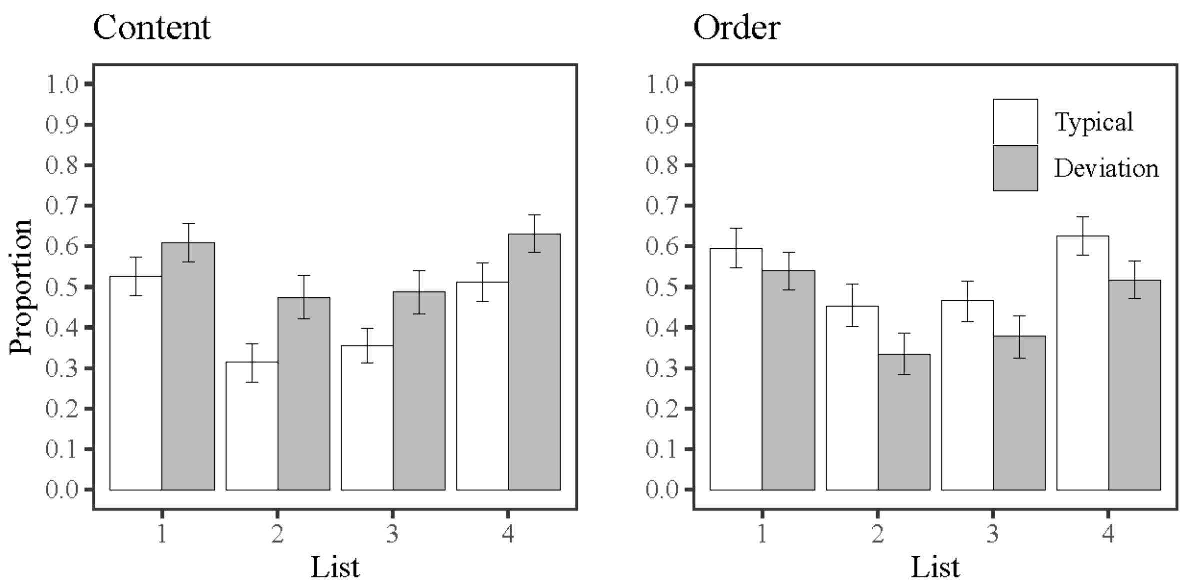

Figure 4. Proportion of correctly recalled words from all lists for content and order deviations (collapsed across delay). Error bars represent 95% CI of the mean.

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.

Internal intrusions: 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.

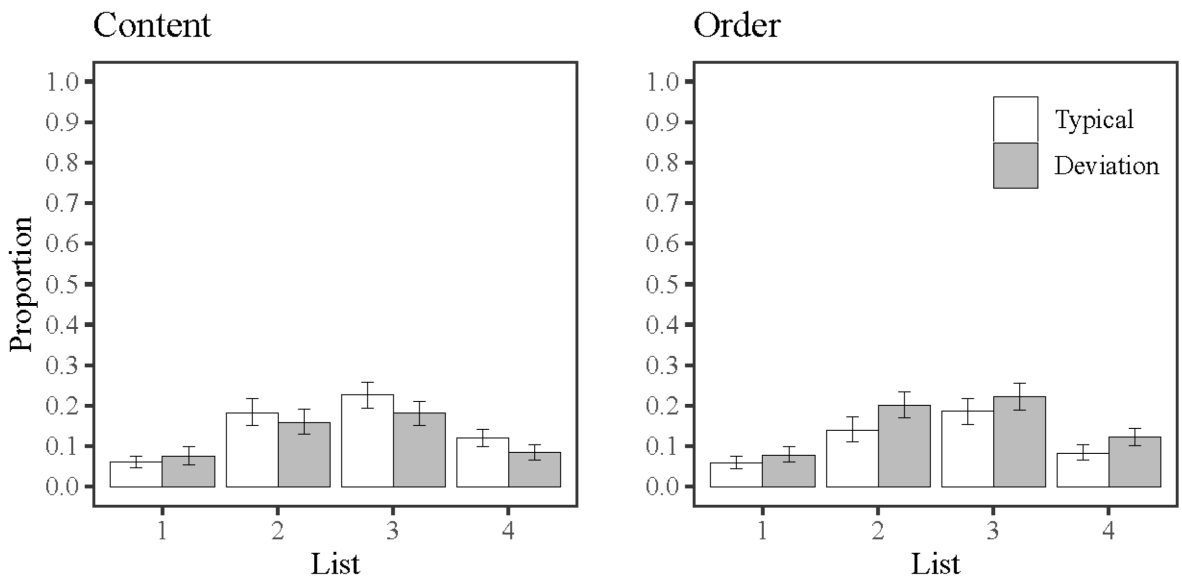

Figure 5. Proportion of internal intrusions in all lists for content and order deviations (collapsed across delay). Error bars represent 95% CI of the mean.

Table 3

Experiment 2: Mean proportion of correct recall and internal intrusions

	Correct recall				Internal intrusions			
	List 4							
Session	Baseline	Content	Order	Both	Baseline	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. Statistics display means and standard deviations.

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]).[6]

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

[6] 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.

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 the deviation (b = 0.21, 95% CI [0.08, 0.34], $t(58)$ = 3.30, p = .002; Figure 6). 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).

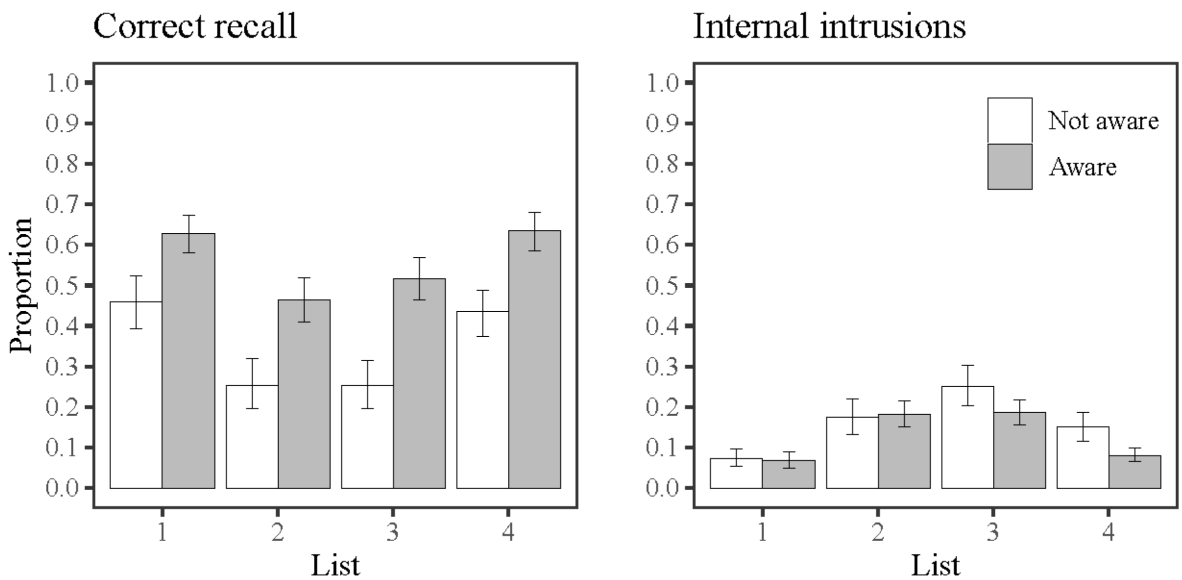

Figure 6. Proportion of correctly recalled words and internal intrusions from all lists for participants who were/were not aware of any deviation (collapsed across delay). Error bars represent 95% CI of the mean.

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.[7] 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 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).

[7] 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.

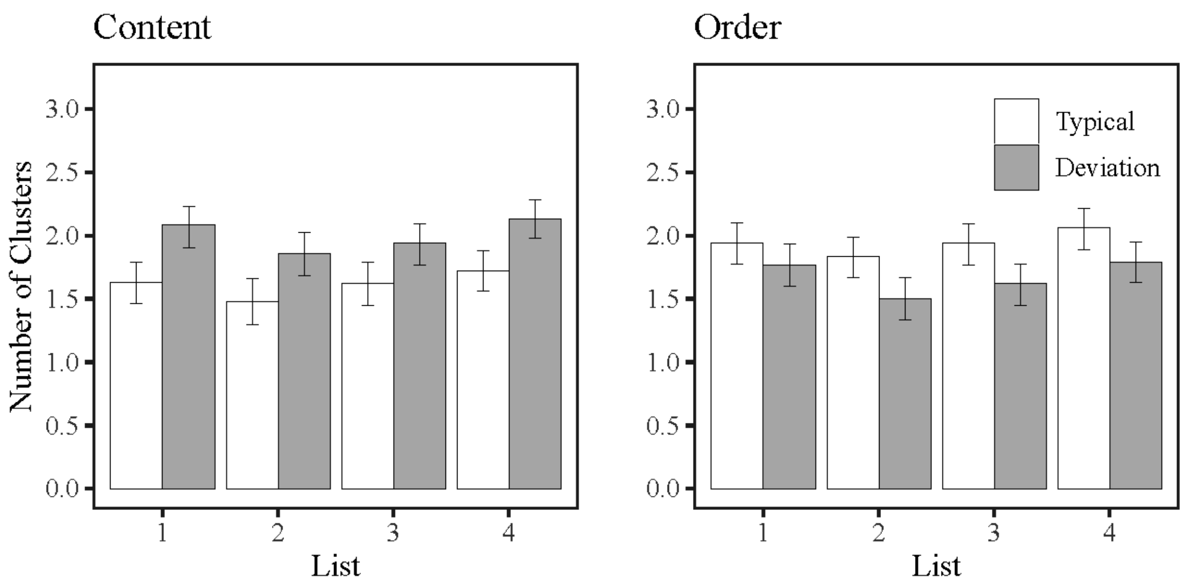

Figure 7. Number of clusters in all lists for content and order deviations (collapsed across delay). Error bars represent 95% CI of the mean.

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, i.e., 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).

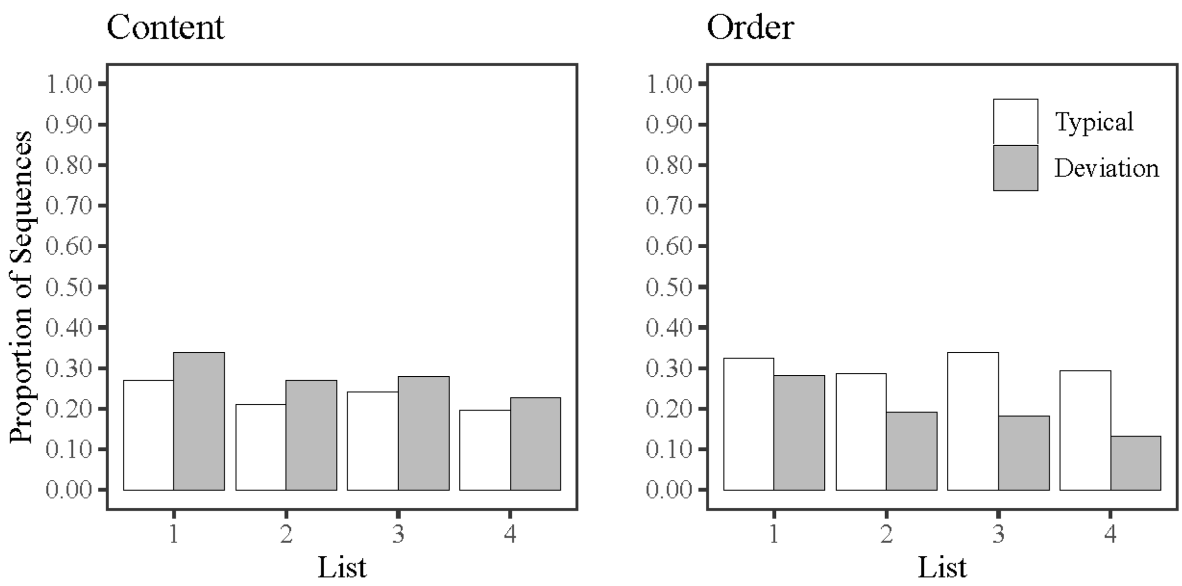

Figure 7. Proportion of correct sequencing in all lists for content and order deviations (collapsed across delay). Error bars represent 95% CI of the mean.

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 from 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 from 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 from 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 (W. F. Brewer, 2000; W. F. Brewer & Nakamura, 1984; W. F. 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 from 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 Supplemental Materials). 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.

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Declaration of Conflict of Interest

The Authors declare that there is no conflict of interest.

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