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The underlying processes of episodic memory development: From a unique contribution of representation to the increasing use of semantic organization supported by cognitive control

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Declaration of interest

None.

CReditT authorship contribution statement

AF and LT conceived and designed the study. AF and HRW collected the data. AF and AW analyzed the data. AF and LT wrote the original manuscript. HRW and AW reviewed and edited previous versions of the manuscript.

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Abstract

Episodic memory development is linked to better clustering of items semantically related at recall. Previous studies have suggested that the use of clustering occurs relatively late in children's development, and does not systematically lead to benefits. Here, we investigated how Control (the fluid goal-directed cognitive processes supporting adaptive and flexible behaviors) and Representation (crystallized schemas or general knowledge about the world) contribute to recall and clustering in childhood. To this end, 104 children aged from 8 to 13 years-old were administered a free-recall task and tests assessing Control and Representation. Results showed that the use of clustering, although it emerges from 8 years-old, was only beneficial for recall after 11 years-old. Regarding the respective contribution of Control and Representation, we observed that only Representation accounted for recall in the younger children (8-11 years), whereas both Representation, but to a lesser extent, and clustering supported by Control, improved recall from age 12. These results offer new insights into the development of episodic memory through childhood and the underlying mechanisms.

Key words: episodic memory development, clustering, cognitive control, knowledge, utilization deficiency

Introduction

Episodic memory is the ability to remember past events in a particular place and time. This ability is crucial for everyday activities, such as remembering where we left our bikes when we arrived at work in the morning, or the name of the restaurant where we had arranged to meet friends. It also plays an important role in how our identity is built up over time (Piolino et al., 2009). Given the importance of episodic memory in our daily functioning, it is therefore crucial to understand how it develops from childhood to adulthood and what the underlying mechanisms are that promote this process. The capacity to form semantic connections between entities (e.g., objects, events or persons), known as clustering, plays a significant role in the development of episodic memory performance (Schneider, 2015). The present study sought to better understand how the use of this clustering strategy in childhood supports better episodic memory performance by examining the potential contributions of fluid processes of cognitive control (hereafter Control) and crystallized knowledge or representations of the world (hereafter Representation).

One of the most efficient ways of improving performance in a free-recall memory task with no external cues is to organize items semantically (Bousfield, 1953). When presented with semantically related items (lexical sets, e.g., ‘glass’, ‘cup’, ‘saucer’), although it has been first reported that children aged 9 to 10 years show some evidence of clustering, organizing their responses by recalling items in semantic or adjacent groups (Hasselhorn, 1990), more recent studies showed that this ability progressively develops from 7 to 13 years-old (e.g., Bjorklund & de Marchena, 1984; Bjorklund & Jacobs, 1985; Schleepen & Jonkman, 2012; Schwenck et al., 2007; for a review see Ornstein et al., 2010). Indeed, a recent cognitive modelling study has shown that memory for individual items is the only factor contributing to enhance memory performance in 7-year-old children whereas encoding items as clusters increasingly predicts better performance for children older than 10 years-old (Horn et al., 2021).

Although clustering is generally efficient for memory, it does not systematically lead to better performance, even when applied spontaneously (Bjorklund et al., 1994; Clerc et al., 2014; Miller & Seier, 1994). This phenomenon is known as‘utilization deficiency’, the use of a potentially efficient strategy with no corresponding enhancement of recall (for a review, see Clerc, 2013). This deficiency can be explained by the fact that this mnemonic strategy is resource consuming and may be so effortful when first applied that it leaves insufficient resources to enhance memory performance (Bjorklund & Harnishfeger, 1987; Miller, 2000; Miller et al., 1991). Utilization deficiency has been studied extensively in memory and is present from 3 to at least 11 years of age (Bjorklund et al., 1992; Blumberg & Torenberg, 2005; Miller & Seier, 1994). Some studies have identified several factors that increase utilization deficiency. For instance, increasing cognitive load by inducing an interference task (e.g., finger tapping) during the encoding and at recall leads to more utilization deficiency in 9 year-old children but not in 13 year-old children and adults (Bjorklund & Harnishfeger, 1987). Relatedly, higher utilization deficiency is observed among children with learning disabilities (Gaultney, 1998), scoring low on working memory (i.e., the ability to maintain and update information in mind) tasks (Schleepen & Jonkman, 2012) or on tasks assessing the amount of vocabulary they know (also referred to as knowledge base; Miller, 1994). Thus, the efficiency of clustering might be potentially associated with cognitive control and representation capacities.

Of particular interest, grounded in the original piece of work of Horn and Cattell (1967), Craik and Bialystok (2006) developed a theoretical framework, which aimed to account for cognitive changes across the lifespan based on two main mechanisms: Control (cognitive control), referring to the fluid goal-directed cognitive processes supporting adaptive and flexible behaviors; and Representation (knowledge base), characterizing the crystallized schemas or general knowledge about the world. This dissociative Control/Representation theory is well-supported by neural development studies, which have shown that Control is mainly supported by the frontal lobes, the last cerebral regions to develop, only reaching maturity after adolescence (e.g., Anderson et al., 2008; Badre, 2008; Bunge et al., 2002; Crone & Steinbeis, 2017), resulting in a slow and continuous progression of Control capacities throughout childhood and adolescence (for a review, see Diamond, 2013). In contrast, Representation is associated with posterior cerebral networks, which mature much earlier than frontal regions (Craik & Bialystok, 2008; Ofen et al., 2007), and young children have been shown to have a good knowledge base about various topics (e.g., toys, sports), developing progressively with age (Chi, 1981; Murphy et al., 2003; Schneider et al., 1989).

Both Control and Representation are critical for episodic memory development. First, representation provides the base for understanding and making sense of a memory task (e.g., knowing the words to be remembered), and enhances memory through better encoding performance (Rawson & Van Overschelde, 2008). Furthermore, a reported robust finding is that a good knowledge base predicts better episodic memory performance in children, as it improves the ease of activating information stored in semantic memory. This in turn improves the use of resources required for other cognitive operations, such as encoding and retrieval strategies (Bjorklund, 1987; Coutanche & Thompson-Schill, 2014), as well as selecting the best strategy for improved memory performance (Robertson & Köhler, 2007). The relation between episodic memory development and Control has mainly been examined using the Source-Monitoring Framework (Johnson et al., 1993) when children have to make source judgments on a decision, which is therefore a test for episodic memory. Findings have been mixed, with some research showing a positive relation between Control, and more particularly working memory and inhibition, and episodic memory in children as young as 3.5 years of age (e.g., Earhart & Roberts, 2014; Karpinski & Scullin, 2009; Hala et al., 2016; Rajan et al., 2014; Roberts & Powell, 2005) whereas others did not (Bruck & Melnyk, 2004; Drummey &

Newcombe, 2002; Roebers & Schneider, 2005). In older children, a study has highlighted that only cognitive flexibility was associated with performance on an episodic memory task (Blankenship & Bell, 2015) and overall, from 8 years of age, this performance is linked to greater activation in the frontal lobes, more particularly in the prefrontal cortex (e.g., Ofen et al., 2007) As such, cognitive control is likely to be involved in episodic memory performance but its contribution and the role played by each cognitive components in this process are still unclear. Importantly, it remains unknown whether these two mechanisms contribute similarly or differently to episodic memory performance in children, and more importantly, which of these two mechanisms enable the increasing use of a clustering strategy in a free-recall task, from the time this strategy is first used (8-9 years-old) to when it is used efficiently (from 13 years-old).

The present study investigated the respective contributions of Control and Representation to recall in general, and more precisely, to the use of a clustering strategy. To this end, we tested 8- to 13 years-old children on a well-established free-recall task (Taconnat et al., 2009; Taconnat et al., 2020) tapping episodic memory processes, where the words could be organized into semantic clusters during recall. Performance was indexed by recall and the well-established Adjusted Ratio of Clustering (ARC) score (Roenker et al., 1971) was used to assess clustering performance (see Data processing). They also performed three Control tasks examining the multiple components of Control (e.g., McCabe et al., 2010) and two Representation tasks. We first focused our analyses on the whole group by using age as a continuous variable. By doing so, we expected that the use of clustering would not systematically predict better recall performance in younger children contrary to older children. Moreover, given the age range of our sample, we predicted Representation to significantly predict recall over Control. However, to get a clearer picture of developmental changes, we analyzed associations between the different measures (recall, clustering or ARC, Control and

Representation) and expected that better recall would be related to Representation abilities in younger children, whereas Control would play an increasing role in the use of clustering to benefit recall in older children.

Method

Participants

The sample comprised 104 French children aged from 8 to 13 years-old (M_{age} = 10 (years); 7(months), SD_{age} = 1;6, 56 girls). This sample size was determined by an a priori power analysis ran with G*Power, which indicated that for a given medium effect size of .15 and an alpha power of .80, a minimum sample of 85 participants was required. All participants were mostly Caucasian and came from middle to high socio-economic backgrounds, although this information was not collected. They were recruited in French primary and secondary schools, selected by their teachers as normal to good performers, with a good level of language (French). They were tested in a quiet room within the school. Parental and personal consent was received for each participant. This study was approved by the Ethics Committee of the Department of Psychology of the University of Tours and by the participating schools.

Procedure

Each child was tested individually in a classroom at school by one trained experimenter in a single 30- to 45-minute session. Children first performed the recall task, followed by the cognitive control and representational tasks (these tasks were counter-balanced).

Recall task

Children were first told that they were going to play a short memory game. A categorized list of 20 words (five categories of four words; see Supplementary Material, I) was presented once to each child on a monitor, at a pace of one word every five seconds. Children had to read aloud each word. The words were arranged and presented in a pseudorandom order, so that no two words from the same category were presented sequentially. Children were not informed about the possible structuring of lists. The words in each of the five categories were selected from Marchal and Nicolas (2003). The categories were matched with respect to word length, word frequency (Brulex databse; Content et al., 1990), and typicality of semantic category. The words were 5 to 8 letters long, with 2 to 3 syllables, were all concrete nouns, and had overall the same frequency of use (see Supplementary Material, I). Age of acquisition of these words was taken into account to ensure that the youngest children knew all the words (Lachaud, 2007).

After presentation of the list, children performed a letter-comparison task (XO) for forty-five seconds to avoid any recency effect on the recall task. In this task, children had to tell whether the pairs of letters, either both O, both X or an O and an X, were similar or different. They were then asked to orally recall as many words as possible from the presented list with no time limit, and these were recorded by the experimenter. By consequence, any difficulty in writing was avoided, particularly in the younger children. They were also told to indicate to the experimenter when they thought they could not recall any further words in order to terminate the recall phase. Upon completion of the recall task, participants relaxed for a few minutes before taking the remaining tests.

After the recall task, the experimenter interviewed the younger children (8- to 11-year-old children) about their knowledge of the words and the categories (e.g., “Can you show me where is your shoulder?”), and all showed perfect knowledge of the words and the category to which each word belonged.

Cognitive control tasks

Cognitive control was assessed using three widely used cognitive control tasks suitable for use with children as young as 8 years-old: the Stroop Color-Word Test (SCWT; e.g., Homack & Riccio, 2004; Okuniewska & Maryniak, 2012), the N-Back test (e.g., Pelegrina et al., 2015) and the Wisconsin Card Sorting Test (WCST; Chelune & Baer, 1986). For the SCWT and N-Back, practice trials were provided to ensure that each child understood the instructions. All children successfully completed the practice trials and showed perfect understanding of the cognitive control tasks.

The SCWT

Two subtests of the SCWT (Stroop, 1935) were administered (paper and pencil task): the Color-Naming subtest (congruent trials), in which children have to name the color of crosses (XXX), and the Color–Word Interference subtest (incongruent trials), in which they have to name the color of color words while ignoring the printed word. In each subtest, children were required to name colors aloud as quickly as possible for forty-five seconds, and the number of correct responses was recorded. Before completing each subtest, three words were randomly selected on the paper sheet by the experimenter and children were asked to read them according to the rule to ensure they understood the instructions. Following the recommendations of Li and Bosman (1996), a score was computed as follows:

$$\frac{(Colour\ Naming\ score) - (ColourWord\ Interference\ score)}{Colour\ Naming\ score}$$

The N-Back test

A computerized version of the 2-Back test (Kirchner, 1958) was administered. Children had to compare the currently presented letter to the one presented two trials before and were instructed to press the “yes” key only when the two subsequent letters were the same; otherwise, they should press the “no” key. Five practice trials were given to the children to ensure they understood the instructions. This was followed by test trials. The score was the number of correct responses.

The WCST

The standard WCST (Heaton et al., 1993) was administered. In a computerized version of this task, four target cards were shown on the screen throughout the experiment, and the response card was shown at the bottom of the screen. There were 64 response cards arranged in pseudo-random order. All of the target cards and response cards differed in three ways: by color (red, green, yellow, blue), by shape (triangle, circle, square, star) and by number (1, 2, 3, 4). Each time a response card was displayed, participants had to click on the corresponding target card. They were given feedback indicating whether each response was correct or incorrect. There was no time limit. The first relevant sorting rule was color, and after ten successive correct placements, the sorting rule changed, first to shape and then to number. This change was not announced but had to be inferred from the feedback. If this phase was completed successfully, the task continued, going back to color sorting and so on until all the 128 response cards had been used. The specific measure retained here was the number of perseverative errors, that is, the number of incidences in which the participant continued to use the same response strategy after a switch in sorting rule. This measure is the most representative measure of the cognitive control factor (Salthouse et al., 2003).

Scores for the SCWT and WCST were multiplied by -1 to ensure that higher scores reflected better performance.

Representational tasks

Representation was assessed using the Vocabulary and Information subtests of the WISC-IV (Wechsler et al., 2012).

Vocabulary test

The vocabulary subtest of the WISC-IV consists of 31 words that the children were asked to define (e.g., “what is an umbrella?”). The score is the sum of correct answers (two points for a complete definition and one point for an incomplete definition).

Information test

The information test used for the children consists of 33 general knowledge questions (e.g., “What are the four seasons?”). The score was the sum of correct answers (one point for each correct response).

Because the vocabulary and information subtests of the two scales do not have the same number of items, performance was measured by dividing the number of completed items by the total number of items (ratio). For both tests, higher scores indicate better performance.

Data processing

ARC

The number of correctly recalled words in the free-recall task was one of the dependent variables. However, we also calculated an Adjusted Ratio of Clustering score (ARC), developed by Roenker et al. (1971), as a measure of clustering at recall. It ranges from 0 to 1; a score of 0 indicates chance clustering, and a score of 1 indicates perfect clustering. It is computed using the following formula:

$$ARC = \frac{R - E(R)}{maxR - E(R)}$$

> *"…where R is the total number of category repetitions, max R is the maximum possible number of category repetitions, and E(R) is the expected (chance) number of category repetitions"* (Roenker et al., 1971, p. 46).

It adjusts for the differences in the total number of items recalled. Thus, ARC scores are relatively independent of the recall score, since a low score at recall may lead to a high ARC score if the few words are recalled in an organized fashion.

Control and Representation Indices

To compute Control and Representation indices based on the tasks used here, we first conducted a Principal Component Analysis (PCA) to test the dissociation between these processes. This analysis can be found in Supplementary Material (B). The PCA yielded two main factors, corresponding to the Control and Representation factors. We computed two scores for each participant, one for Control index (corresponding to the means of the z-scores of the WCST, SCWT and N-Back) and one for the Representation index (corresponding to the means of the z-scores of the Vocabulary and Information).

Data analyses

Data were analyzed using R version 4.1.0 (Team R Core, 2021). We first analyzed how age, ARC, Control and Representation are associated with recall. To this aim, we conducted hierarchical regression analyses using the *stats* package with age (continuous) as a first predictor (Step 1), followed by ARC (Step 2), Control (Step 3) and Representation (Step 4). Subsequently, we entered each possible interaction in the following steps. Plots of significant interactions were obtained with the *graphics* package and the function *coplot()*. The advantage of these analyses was to consider the whole sample. Following these analyses, we examined the association between recall, ARC, Control and Representation as a function of age group by conducting multiple Pearson correlational analyses using the *Hmisc* package with the Benjamini and Hochberg correction (Benjamini & Hochberg, 1995) to account for both false positives and false negatives (see III in Supplemental Material for correlation including recall, ARC and each Control and Representation tasks in the whole group in each age group separately). Therefore, for the course of these correlational analyses, children were split into three age groups: 8-9 year-olds (*n* = 35, M_{age} = 8;9, SD_{age} = 0;4, 18 girls), 10-11 year-olds (*n* = 39, M_{age} = 10;9, SD_{age} = 0;6 22 girls) and 12-13 year-olds (*n* = 30, M_{age} = 12;5, SD_{age} = 0;4, 16 girls).**Erreur ! Signet non défini.**

Results

Hierarchical linear regression

Results of the hierarchical regression analysis are reported in Table 1. This analysis revealed that at Stage one, Age contributed significantly to the regression model, $F(1, 102) = 126.62$, $p < .001$, and accounted for 42% of the variation in Recall. Introducing ARC explained an additional 4.37% of variation in Recall, and this change in R^2 was significant, $F(1, 101) =$

11.76, $p < .001$. However, adding Control at Stage three to the regression model only explained an additional variation of 0.005% and this change was not significant, $F(1, 100) = .16$, $p = .689$. Nevertheless, when Representation was added at Stage four, it significantly explained an additional variation of 10.52%, $F(1, 99) = 32.00$, $p < .001$. Moreover, when adding the interaction Age x ARC, this resulted in a significant change in R^2 of 10.88%, $F(1, 98) = 33.12$, $p < .001$. The addition of other interactions did not significantly add variation in the explanation of the variable Recall, *ps* > .129. As such, the model with Age, ARC, Control, Representation and the interaction Age x ARC accounted for 66.92% of the variance in Recall. In this model, Age and ARC significantly interacted, $t = 5.68$, $p < .001$. As shown in Figure 1, this interaction revealed that although most younger children had an ARC inferior to .5 and recalled less than 50% of the words, even those who engage in a clustering strategy (ARC superior to .5 so greater than the level expected by chance; see Coyle & Bjorklund, 1997; Schleepen & Jonkman, 2012) still recalled less than 50% of the words. Conversely, older children increasingly implemented a clustering strategy, which resulted in better recall. Phrased differently, this indicated that younger children showed a utilization deficiency whereas older children were significantly better at semantically organizing the words, which predicted better recall (Figure 2). Finally, this model revealed a main effect of Representation, $t = 5.93$, $p < .001$, indicating that children with better Representation capacities recalled more words, hence speaking for a key contribution of Representation in children's recall performance.

Table 1. Hierarchical regression analyses predicting Recall performance from Age, semantic strategies (ARC) cognitive control (Control) and knowledge (Representation).

step	Variable	R^2	ΔR^2	β (step5-model)	t (step5-model)
step1	Age	0.411	0.4161***	-0.04	-3.11**
step2	ARC	0.4547	0.0386***	-1.51	-5.23***
step3	Control	0.4552	0.0005	0	0.05
step4	Representation	0.5604	0.1052***	0.08	5.93***
step5	Age x ARC	0.6692	0.1088***	0.15	5.68***
step6	Age x Control	0.6708	0.0016		
step7	Age x Representation	0.6779	0.0071		
step8	ARC x Control	0.6831	0.0052		
step9	ARC x Representation	0.684	0.0009		
step10	Control x Representation	0.6891	0.0051		
step11	Age x ARC x Control	0.6917	0.0026		
step12	Age x ARC x Representation	0.6995	0.0078		
step13	Age x ARC x Control x Representation	0.7043	0.0048		

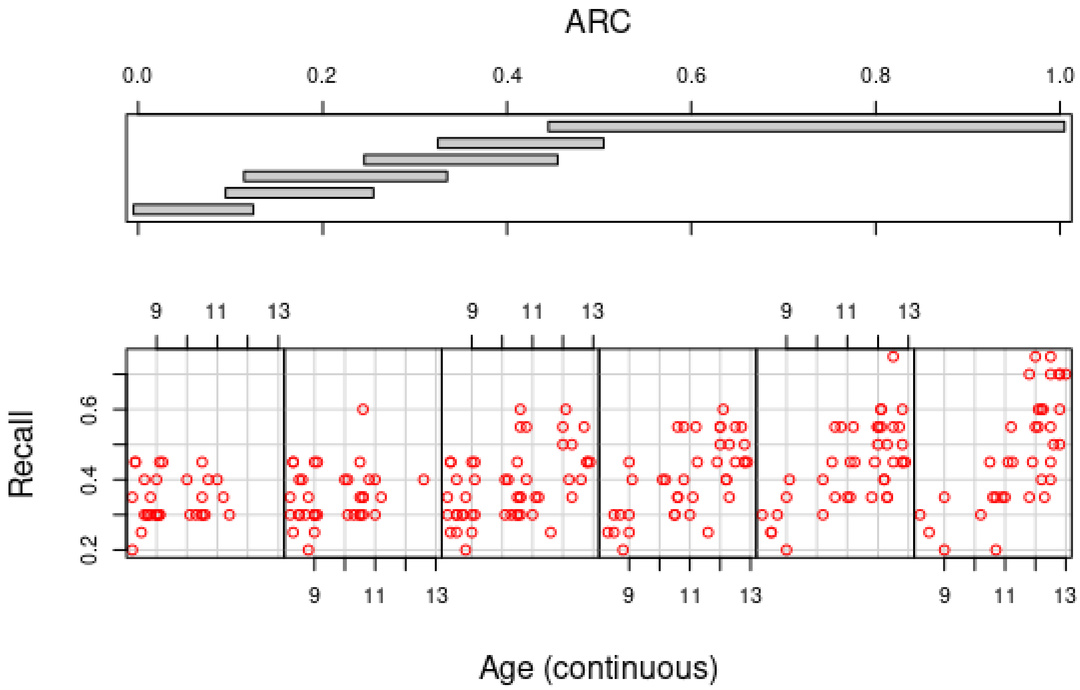

Figure 1. Conditioning plot representing the interaction between Age and ARC. Gray bars represent how closely observations fall within the ARC range and each red dot represents a child participant. Younger children showed a utilization deficiency whereas older children successfully implemented an organization strategy translated in better recall.

Correlation analyses

Results of the correlation analyses for each age group are presented in Table 2. First, these analyses revealed that for both 8-9 and 10-11-year-old children, recall was only positively associated with Representation ($r = .77$ and $r = .66$, $ps < .001$) whereas Control and ARC were not, $ps > .352$. However, for 10-11 year-old children, Control was associated with ARC ($r = .55$, $p < .001$). Finally, for the oldest children (12-13 year-olds), we observed that both ARC and Representation were positively correlated with recall ($r = .57$ and $r = .52$, $ps < .034$), but not Control, $p = .227$. Finally, Control was associated with ARC ($r = .46$, $p < .021$). Correlation comparisons based on Guilford (1965)'s formula indicated that the strength of the correlation between recall and Representation did not differ between age groups, $ps = .073$. Finally, the correlation between ARC and Control was not statistically different between 10-11 year-olds and 12-13 year-olds, *Z* = -.476, *p* = .634.

Table 2. Correlational analyses between ARC, Control and Representation for each age group.

8-9 years (*n* = 35)			
	Recall	ARC	Control
ARC	-.23		
Control	-.02	.28	
Representation	.78***	.02	-.14
10-11 years (*n* = 39)			
	Recall	ARC	Control
ARC	.28		
Control	.12	.55***	
Representation	.66***	.15	.03
12-13 years (*n* = 30)			
	Recall	ARC	Control
ARC	.57**		
Control	.23	.46*	
Representation	.52**	.37	.33

Note: * = $p < .05$, ** = $p < .010$, *** = $p < .001$.

Discussion

The present study charted out the contributions of two potential underlying mechanisms, Control and Representation (Craik & Bialystok, 2006, 2008), to recall performance and the use of clustering in a free-recall episodic-memory task, developmentally in children from 8- to 13-years-old. This study yielded several important results, discussed below, that refine our understanding of episodic memory and mnemonic strategy development and their underlying mechanisms.

First, we observed that few children under the age of 11 years actively implemented clustering during recall as evidenced by having an ARC score inferior to .5. It was only from the age of 12-13 that most children adopted clustering. This result corroborates previous studies showing that adopting this strategy during an episodic memory task emerges around 8 years of age, but it is only later that children begin to systematically engage in this type of organizational behavior, with an apparent switch occurring after the age of 12 years (Bjorklund & de Marchena, 1984; Bjorklund & Jacobs, 1985; Horn et al., 2020; Schleepen & Jonkman, 2012). Interestingly, the interaction between age and ARC on recall indicated that only older children who were strategy users (ARC superior to .5) showed better recall performance than non-strategy users (ARC inferior to .5) whereas in younger children, those implementing clustering did not show improved performance during recall. This was backed up with our correlational analyses showing that ARC was positively associated to recall only in 12-13-year-olds, and not in younger children. In other words, children up to the age of 11 who used clustering did not benefit from it and showed a utilization deficiency. This result is in agreement with previous research reporting that this phenomenon occurs up to late childhood (Clerc et al., 2014).

As stated in the Introduction, the causes of utilization deficiency are multiple, but with our measures of Control and Representation based on Craik and Bialystok's model (2006, 2008), we were able to observe how these potential underlying mechanisms were associated with recall and clustering. For instance, regression analyses revealed that overall recall was predicted by Representation and not Control. However, when looking at correlational analyses between the three different age groups, it appeared that up to the age of 12 years, only Representation was associated with recall, confirming previous studies on the critical role of knowledge in episodic memory in (e.g., Chi, 1978; Lindberg, 1980; Murphy et al., 2003). Consistent with our hypothesis, after 12 years-old, although Representation still accounted for better recall, this was also mostly driven by the use of clustering. Interestingly, we observed that for children older than 10 years, ARC was correlated with Control. However, it was only for the oldest age group (12-13 year-olds) that recall was positively associated with ARC. This indicated that although cognitive control was associated with the implementation of semantic strategy, this was not associated with better recall in 10-11 year-old children, and was therefore characteristic of a utilization deficiency. This was in line with proposals stating that for younger children, the use of difficult mnemonic strategy such as clustering is so resource consuming that it might be so effortful and leaves insufficient resources to enhance memory performance (Bjorklund & Harnishfeger, 1987; Miller, 2000; Miller et al., 1991). Conversely, the association between Control and ARC was smaller for older children, potentially suggesting that these children had enough resources to actually benefit recall. This was in line with previous studies in children finding that clustering is mediated by working memory (Schleepen & Jonkman, 2012), and also by studies with elderly populations highlighting that misuse of clustering during recall is mostly due to decrements in Control (Taconnat et al., 2007, Taconnat et al., 2009).

An interesting point arising from our data is that Control per se was not predictive of nor associated with recall. This is in line with a previous study showing that most cognitive control components are not associated with episodic memory in 9-12 year-old children, but only cognitive flexibility (Blankenship & Bell, 2015). However, a limitation of our measure of control is that the index only considered a measure of components of cognitive control based on the well-established framework (Miyake et al., 2000; Miyake & Friedman, 2012), and did not take into consideration how *modes* of control are related to recall, or even clustering. For instance, throughout the development, children show better abilities to engage cognitive control both in a proactive manner (i.e., preparing in advance what to do; see Chevalier, 2015) and in self-directed fashion (i.e., without external aids to guide them about what to do (Barker & Munakata, 2015; Frick et al., 2021). Therefore, an interesting avenue for future research is to explore how these modes of cognitive control are associated with the increasing successful implementation of clustering in children. Nevertheless, there is also evidence that besides controlled processes, recall is strongly influenced by automatic processes (Tulving, 1983). For instance, it has been shown that individuals can recall words that they then cannot recognize and remember as having been seen previously due to semantic priming, a phenomenon called recognition failures (e.g., Ozubko et al., 2021). Moreover, dividing attention affects recollection but not remember-know judgments during free-recall, speaking in favor of a substantial influence of automatic processes on this type of recall in episodic memory (McCabe et al., 2011). However, to what extent automatic processes contribute to recall performance in children's episodic memory is still unclear and future studies should be carried out on this issue.

The latter point raised in the previous paragraph relates to one of the several limitations of the current study. Indeed, we set a time-window of 45 seconds between encoding and retrieval as many previous studies on episodic memory used a time interval of less than in minute between these two processes (e.g., Kuhlmann & Touron, 2016; Taconnat et al., 2009; Uittenhove et al., 2015). However, this limited time window might not allow for strong memory consolidation and retrieval involving autonoetic consciousness, that is, the feeling of reliving events with awareness of time, place, and coherent bindings of spatial and temporal contextual details. As such, future studies should contrast between shorter and longer time windows between encoding and retrieval to examine to what extent it influences memory performance and clustering both in children and adults. Moreover, we believe that adding a measure of familiarity, such as asking the participants whether they remember exactly the moment they encoded an item (e.g., remember-know-guess judgments), to further investigate whether items with better encoding are more likely to be recalled and grouped into semantic clusters. Relatedly, although the ARC measure is a reliable proxy of clustering, it nevertheless merges both encoding, storage and retrieval processes into one measure. Therefore, other methods such as a cognitive modelling approach could be used in the future to better disentangle the relative contributions of Representation and Control to encoding and retrieval underlying recall and clustering (see Horn et al., 2021 for a cognitive modelling approach on clustering in children' episodic memory). Another limitation relates to the use of inter-individual comparisons instead of intra-individual comparisons when looking at organizational behaviors, and the former potentially creates more utilization deficiencies than the latter and this can lead to misleading conclusions about age group comparisons of utilization deficiency (Schlagmüller & Schneider, 2002). As the literature is currently mixed between using one or the other approach (e.g., Horn et al., 2021; Miotto et al., 2020; Schleepen & Jonkman, 2011), a potential future study should investigate to what extent the use of these two approaches does influence the observed results regarding organizational behaviors, and more especially utilization deficiency and which types (Bjorklund et al., 1997). Finally, we acknowledge that although our sample size was large enough for regression analyses (see Participants section), it was relatively small for correlational analyses as Schönbrodt and Perugini (2013) have demonstrated that correlation coefficients tend to stabilize with a sample size of around 250 participants. Future studies should therefore try to test more children, although achieving such a sample size is particularly challenging in developmental research.

To conclude, the present paper confirms that successfully implementing clustering in a free-recall memory task when items are semantically related emerges relatively late during childhood. Moreover, adopting such a strategy does not systematically lead to better performance as evidenced by a utilization deficiency in younger children as compared to older children, potentially because this strategy is cognitively costly. Rather, recall in children younger than 11 years-old is mainly based on knowledge, whereas for older children it is mostly based on clustering supported mainly supported by cognitive control, and to a lesser extent on Representation.

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