The Version of Scholarly Record of this Article is published in *JOURNAL OF COGNITIVE PSYCHOLOGY*, available online at: http://dx.doi.org/10.1080/20445911.2016.1270950. Note that this article may not exactly replicate the final version published in *Journal of Cognitive Psychology*.

David Giofrè, Carretti, B., & Belacchi, C. (2017). How semantic organization influences primary school children's working memory. *Journal of Cognitive Psychology*. doi:10.1080/20445911.2016.1270950

How semantic organization influences primary school children's working memory

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Manuscript Accepted 06/12/2016

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Abstract

The present study focuses on the semantic organization of material in working memory (WM). We developed a measure in which students memorized unrelated words from lists. In our study, we manipulated the association between words in the lists. The material was organized so as to elicit a semantic organization (categorical and thematic). The task was then administered to a group of 6- to 10-year-old children. The semantic organization of the material prompted a better recall, which depended on the type of semantic organization. In the same vein, the number of intrusion errors was influenced by the semantic links between words and was higher when words in the list were associated categorically. These results seemed to depend partly on the participants' age, being evident only in the younger children.

Keywords: working memory; long-term memory; semantic; categorical; children.

How semantic organization influences primary school children's working memory

The present study analyzed how the semantic organization of material in long-term memory (LTM) may influence recall in working memory (WM). For this purpose, the association between the words in a WM task was manipulated, distinguishing between categorical and thematic links.

WM is a limited-capacity system that enables information to be stored temporarily and manipulated. Various models of WM have been described. The classical WM model initially proposed by Baddeley and Hitch (1974) had three components: a central executive system responsible for controlling resources and monitoring information processing across representational domains; and two domain-specific slave systems governing the storage of information, i.e. the phonological loop for handling the temporary storage of verbal input and the visuospatial sketchpad, which specializes in retaining and manipulating visual and spatial representations . This classical WM model was well received but several problems emerged after its publication, such as the fact that the model did not consider the relationship between WM and LTM.

This connection between WM and LTM was developed in numerous subsequent models. A very influential paper by Ericsson and Kintsch introduced the concept of long-term working memory (LT-WM). Studying a particular group of experts in chess and in mental calculation, they demonstrated that their sample's extremely good performance in this specific domain was impossible to justify considering WM alone; it could only be achieved by retrieving knowledge from their LTM, which enables information to be kept accessible by means of information cues from short-term memory. The resulting model was initially applied only to skilled performers, such as waiters or chess players, but other models postulated normal participants' access to their LTM too.

As a result, while the original WM model had not foreseen the retrieval of information from LTM, subsequent models incorporated this feature. One of the first models to take access to LTM into account was proposed by Cowan (1995), who postulated that information from LTM was activated in WM by what he called the focus of attention. Baddeley (2000) also proposed a revised model that included a new component, called the “episodic buffer”, presumed to be capable of storing information in a multi-dimensional code, providing a temporary interface between the two slave systems and LTM. Several studies suggested that the way in which material is organized - using various types of association (based on the chunking phenomenon) – correlates with the recall of the information (Mathy & Feldman, 2012; Miller, 1956). A chunk enables individuals’ storage capacity to be expanded by grouping several items (e.g., words or numbers) into a single representation (Tulving& Craik, 2000). In particular, the semantic and/or syntactic organization of information should generate a processing advantage on the grounds of both chunking in LTM and episodic buffer (EB) activity.

As regards the role of semantic organization on word recall, for example, it is well known that lists of categorically related items are remembered better than lists of unrelated words (Bower, 1970) and that the integration of linguistic material is automatic and involves no executive resources (Baddeley, Hitch, & Allen, 2009; Jefferies, Lambon Ralph, & Baddeley, 2004). The fact that semantic/linguistic mechanisms are independent of executive resources has been demonstrated in children too. Evidence has been found of both younger (5- to 6-year-old) and older (8- to 9-year-old) children utilizing semantic organization (Kapikian & Briscoe, 2012). Although the authors expected to find greater benefits of semantic organization in the younger age group, the older and younger children ultimately drew a comparable advantage from the semantic/schematic organization of the material .

The long-term activation of information is not necessarily related to a better recall. In fact, there is evidence to suggest that accessing LTM may also produce more “intrusions” (i.e., the recall of words that were presented but that should not be recalled) in some children (Carretti, Cornoldi, De Beni, Palladino, 2004). This effect seems to be particularly relevant for children with reading comprehension difficulties or children who are poor problem-solvers (e.g., Borella, Carretti, & Pellegrina, 2010). The intrusion issue seems to relate to difficulties in inhibiting irrelevant information in WM (e.g., Carretti et al., 2004; Palladino, Cornoldi, De Beni, & Pazzaglia, 2001;

Passolunghi, Cornoldi, & De Liberto., 1999; Swanson, Howard, & Sáez, 2006). As children develop, they become less and less likely to make intrusion errors. In fact, their memory resources, processing speed and ability to inhibit irrelevant information all improve (Demetriou, Christou, Spanoudis, & Platsidou, 2002).

Semantic representations

The development of the semantic system is closely linked to that of the conceptual system. Vygotsky's theory of concept formation (1986) provides an appropriate framework for studies on semantic system development. According to Vygotsky, concepts are part of a hierarchical and socially-accepted system of knowledge. From a developmental perspective, the formation of concepts involves four stages (heaps, complexes, pseudo concepts and true concepts). During the heap stage, children group together objects that are objectively unrelated, based on chance or subjective impressions. In the complex stage, children group together similar objects by objective but not-relevant or uncommon associations. The transition from the complex stage to the concepts stages is facilitated by pseudo-concepts, which allow abstraction or isolation of more substantial, external, common attributes of the objects. The bonds between the different elements of a pseudo-concept are still associative and experiential, in contrast with the logical and abstract bonds found in the true concept stage. Children and adults can effectively communicate with each other only on the basis of shared abstract concepts that are symbolically related, by using shared language to signify true concepts.

As concepts, semantic representations (or the mental content of the lexicon) have a relational nature, based on greater or lesser correspondence and association between objects, events, and actions. Mandler (1978) introduced the distinction between schematic/thematic (or simply ‘thematic’ from here on) knowledge based on complementary relationships and categorical/taxonomic (‘categorical’ from here on) knowledge based on analogy. The categorical system seems to be shared culturally, coded linguistically, and organized hierarchically: objects are grouped cognitively, forming taxonomies on different levels of generality, based on their intrinsic properties, and irrespective of time and space (Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). The routine application of this system begins from around seven years of age (Nelson, 1996). On the other hand, thematic representations group objects on the basis of the spatial-temporal and experiential components of events, scenarios, and organized contexts; this early-life method of organizing our knowledge of the world (e.g., Bauer & Mandler, 1989) is not confined to the earliest stages of development, but is also active later on and in adulthood (e.g., Nelson, 1996).

The most typical thematic representations are scripts, or stereotypic knowledge structures of routine everyday events and their relevant components (Shank & Abelson, 1977). These representations appear quite early in a child's development and even infants as young as 16 months can grasp the temporal order and causal structure of events (Bauer & Mandler, 1989). Preschoolers are able to form thematic representations of events and report on them, based on their more central components (Nelson, 1996). Thematic information also influences word recall tasks, not only in children aged 7-11 (e.g., Towse, Cowan, Horton, & Whytock, 2008) but also into adolescence and adulthood (e.g., Belacchi et al., 2013).

The scientific debate remains open concerning the development of these thematic and categorical systems. Some studies indicate that thematic associations develop early, before the categorical system (e.g., Benelli, Arcuri, & Lonciari, 1989; Lucariello, Kyratzis, & Nelson, 1992). In contrast, there are also reports indicating that both systems develop together and that no such distinction exists (Blewitt & Krackow, 1992; Blewitt & Toppino, 1991). This latter situation is consistent with other studies of reaction times, and showing that stimuli with semantic associations produce faster responses overall, with no difference between age groups (children versus adults) or type of semantic association (categorical versus thematic) (e.g., Hashimoto, McGregor, & Graham, 2007).

As for the relationship between categorical representation and verbal WM, Belacchi et al., (2011), conducted a study with children aged 6-10 years and with adults. This study showed positive effects of categorically organized knowledge on recall performance. In this study the authors used the listening span test (Daneman & Carpenter, 1980) to compare two types of sentences differing in the underlying cognitive representation: descriptive and categorical. Descriptive sentences were reporting typical properties of objects or events (e.g., a dog is hairy and barks). Categorical sentences were making the categorical membership of that item explicit (e.g., a dog is an animal that barks). The results of the study showed that word recall performance was better with the categorical sentences than with the descriptive ones, but only at the age of 8 and above.

Objectives

In the present study, we aimed to shed light on the role of semantic processes in influencing WM performance. To do so, we developed a new WM task in which the link between words in the lists was manipulated so as to include different semantic links, i.e. the lists could contain words that were unrelated (arbitrarily chosen), categorically associated (e.g., color as a superordinate term that includes red or yellow), or thematically related (e.g., the sea consists of water and salt). No semantic links were made between the words the needed to be remembered. Instead, the words that had to be recalled were semantically linked to other words in the lest that did not actually need to be remembered. The influence of these variables was analyzed in children from 6 to 10 years of age, with attention given to the changing sensitivity to categorical and thematic links in this age group.

There is plenty of research investigating the role of the semantic similarity in WM tasks. For example, research has repeatedly shown that the presence of semantically related information influences recall (see Baddeley, 2012 for a review). In line with this observation, it has been shown that different brain areas are activated during semantic encoding (Demb et al., 1995). Traditional tasks, however, do not facilitate testing of the effect of semantic manipulation during the encoding phase. In fact, semantic association is usually evaluated by free recall tasks in which a list of semantically related words are presented for memorization and recall (Baddeley, 1966). This procedure may implicitly favor the of use of memory strategies during the encoding phase (Tulving & Craik, 2000).Such a dynamic makes it very hard to effectively understand how the activation of semantic links has an impact on recall. To overcome this limitation, we created a task in which the semantic relation was manipulated within a sublist rather than between the words to-be-remembered. Even though we expected to find smaller effects with this procedure, we reasoned that if the effects of the semantic association are robust, we should still be able to see these effects under the modified circumstances of our experimental model.

Our first aim was to test our hypothesis that the thematically and categorically structured materials would be remembered better than the unstructured information. This would be consistent with a large body of literature indicating that semantic links produce a better recall (e.g., Hashimoto et al., 2007). The effect of different types of semantic link (categorical vs. thematic) was also analyzed in terms of the number of recalled words and intrusion errors. Based on the previous literature on individual differences (e.g., Carretti et al., 2004), categorical associations could be expected to prompt more intrusion errors because activating categorical information might make it more difficult to establish a stable retrieval structure during the recall.

Our second aim was to analyze how age modulates the influence of semantic links. We divided participants into two main age groups: younger children (6-7 years old) and older children (8-10 years old). The choice of these age groups was consistent with the developmental literature regarding WM development cycles and showing that these two age groups can be considered separately (e.g., Alloway, Gathercole, & Pickering, 2006; Gathercole, Pickering, Ambridge, & Wearing, 2004) and differ in their level of WM development (Demetriou, Spanoudis, Shayer, et al., 2013; Demetriou, Spanoudis, & Shayer, 2013). From a semantic/linguistic perspective, distinguishing between these two age groups also follows changes in their capacity for semantic organization. In fact, a vertically-organized system does not develop in children before the age of 7, as shown by word association tasks (among others) revealing the so-called syntagmatic-to-paradigmatic shift - from dog-tail to dog-animal, for instance (Nelson, 1977). Some studies suggest that thematic material should, therefore, be recalled better by the young children and that categorical associations should prompt a better recall in older children (Belacchi, Benelli, &

Pantaleone, 2011), while other studies have concluded that this is not necessarily the case (Hashimoto et al., 2007).

In short, the purpose of the present study was to investigate the effect of different semantic associations on WM performance, analyzing both correct recall and intrusion errors. Further, we investigated whether younger and older children respond differently to the linguistic/semantic organization of the material to be remembered.

Method

Participants

The children were included in the study if they had no clinical diagnoses and belonged to no disadvantaged sociocultural or linguistic groups. The initial screening involved a sample of children from 6 to 10 years old (N = 160). The children verbal abilities were evaluated using the verbal meaning and verbal reasoning subtests of the primary mental ability test (PMA; Thurstone & Thurstone, 1963). Based on the inspection of the boxplots, three participants were found univariated outliers, with extremely low scores in the Verbal Meaning (n = 1) or in the Verbal Reasoning (n = 2) subtest, and we decided to exclude these participants from further analyses.[1]

The final sample consisted of 157 participants divided into two age groups: i) younger children attending 1st and 2nd grades (53 females and 42 males; M_{age} = 7.38 [0.59] years); and ii) older children in 3rd to 5th grades (28 females and 34 males, M_{age} = 9.45 [0.99] years). The two groups were comparable in terms of gender, χ^2 (1) = 1.70, p = .193, Cramer's V = .104.

The children were tested during individual sessions lasting approximately 20 minutes in a quiet room away from the classroom.

Materials

Working Memory task

This task was adapted for the present study from the categorization working memory task (De Beni, Palladino, Pazzaglia, & Cornoldi, 1998), in which children are asked to perform a dual task, i.e. to press the spacebar when they hear a number such as one or three, and to recall the last item in a list of words.

The material consisted of word lists containing four words of medium-high frequency. The word lists were arranged into sets containing an increasing number of lists so that the children had to recall from two to six words, and three trials were run for each set. The children were asked to listen to the four words and to press the space bar whenever they heard a numeral. After completing each set, they had to recall the last word on each list, in the right order of presentation. Unlike the original task, the material was developed so as to obtain three different types of word list: i) arbitrary lists, in which the words selected were unrelated (e.g., two, coffee, car, book; the children had to press the spacebar when they heard the word "two", and remember the word "book"); ii) categorical lists, in which two words were categorically related to a third, which was always presented in the fourth position (e.g., yellow, one**,** blue, color; the children had to press the spacebar when they heard the word "one" and remember the word "color"); and iii) thematic lists, in which two words were semantically related to a third, which was always presented in the fourth position (e.g. water, salt, nine, sea; the children had to press the spacebar when they heard the word "nine" and remember the word "sea"). In other words, the semantic link was manipulated within lists, not between lists; the to-be-recalled words were unrelated to each other. Here an example, with words to-be-remembered underlined, of a set of three lists:

water, salt, nine, sea

yellow, one, blue, color

two, coffee, car, book

The numerals used in the word lists were balanced (to obtain the same proportion of ones, twos, and so on). The numerals were always presented in one of the first three positions and there was always one numeral on each list. The lists were perfectly balanced, with the same number of each type of list (arbitrary, categorical and thematic). The words used were all of high-medium frequency and we ensured that their familiarity was balanced in the three types of list. For each set of word lists, the number of each type of list was always the same. Importantly, we pseudo-randomized the lists to avoid presenting two successive lists of the same type within each trial. We also calculated two different scores, one for the overall number of correctly remembered words, and one for the number of intrusions (i.e., words on the list but not in the fourth position). For each list, there was a total of 20 words to be remembered.

Results

Statistical analyses

All the analyses were performed using SPSS 21. We always considered both the statistical significance and the magnitude of the effect, expressed in terms of effect size (ES) according to Cohen's (1988) criteria.

Effect of semantic link

The first set of analyses was performed to understand whether the manipulation of the semantic links between words in the WM task affected the performance.

To this aim, two ANOVAs were run. One ANOVA was run on correct recall and the other was run on the proportion of intrusion errors. Both ANOVAs covered the overall sample, with the different kinds of links (arbitrary, categorical and thematic) serving as a within-subject variable. In the case of correctly recalled words, we found an effect of Semantic link $F(2, 318) = 4.59$, $p = .011$, $\eta^2 = .03$, with a better recall via thematic links (M = 11.94 SD = 3.59) with respect to arbitrary (M = 11.41 SD = 3.59, $p = .012$) and categorical (M = 11.39 SD = 3.72, $p = .044$) ones. The two latter links did not differ from each other.

When the intrusion errors were considered, the effect of semantic links was again significant $F(2, 318) = 6.44$, $p = .002$, $\eta^2 = .04$, with a higher proportion of intrusion errors in the categorical links (M = .16 SD = .28) with respect to arbitrary (M = .10 SD = .22, $p = .003$) ones and to the thematic links (M= .11 SD = .20, $p = .056$). The latter two lings again did not differ from each other.

Effects of the semantic link on WM performance in function of age

To explore the role of age, we run an ANCOVA including age as covariate for the number of correctly recalled words. The effect of semantic links, $F(2, 316) = 4.52$, $p = .012$, $\eta^2_p = .028$, and the interaction between age and semantic links, $F(2, 316) = 3.59$, $p = .029$, $\eta^2_p = .022$, were statistically significant, similar to results of the previous analysis that did not control for age. To deepen the effect of age, we performed a 2 (age group [age 6-7 and 8-10 years old]) × 3 (semantic link [arbitrary, categorical, or thematic]) mixed analysis of variance (ANOVA) on the number of correctly recalled words. We found a significant main effect of age group, $F(1, 155) = 27.43$, $p < .001$, $\eta^2_p = .150$, with a medium ES, older children recalling more words than younger ones. The effect of the semantic link was not significant, $F(2, 310) = 2.74$, $p = .066$, $\eta^2_p = .017$, and the ES was small. The interaction between age group and semantic link was significant, however, $F(2, 310) = 6.11$, $p = .002$, $\eta^2_p = .038$. On post hoc analysis with Bonferroni's correction, only the younger children (6- and 7-year-olds) showed a significant difference between thematic links and the other two types of link (arbitrary, $p < .012$; categorical, $p < .001$) (see Figure 1).

The effect of age was also evaluated on the number of intrusion errors. In this case, the effect of the semantic link, $F(2, 316) = 3.96$, $p = .020$, $\eta^2_p = .028$ was statistically significant, with differences between conditions in similar pattern to the main analysis, while the interaction between age and the semantic link was not $F(2, 316) = 2.62$, $p = .074$, $\eta^2_p = .016$. Considering previous findings which suggest that memory errors are more frequent when a categorical link is present (see for example Carretti, Bellina & Palladino, 2003; De Beni et al., 1998), we performed a 2 (age group [age 6-7 and 8-10 years old]) × 3 (semantic link [arbitrary, categorical, and thematic]) mixed ANOVA on the proportion of intrusion errors. A significant main effect was found for semantic links, $F(2, 310) = 4.28$, $p = .015$, $\eta^2 = .03$, again with a small ES, reflecting the previously-discussed results, but not for age group, $F(1, 155) = 1.24$, $p = .268$, $\eta^2 < .01$. The interaction between age group and semantic link was significant, $F(2, 310) = 4.32$, $p = .015$, $\eta^2_p = .03$, with a small ES. Where this interaction is concerned, the difference only emerged for the younger children, who made more intrusion errors associated with categorical links than with arbitrary ($p < .001$) or thematic ($p = .011$) links (see Figure 2). The effects were also confirmed by a series of univariated ANOVAs.[2]

Figure 1 and 2 about here

Discussion

The main goal of this paper is to explore the influence of semantic links between words on performance in a WM task. The verbal WM task originally proposed by De Beni et al. (1998) was adapted so that the association between the words was of three types: in one part of the our experiment's modified task, the words were linked by a categorical association, in another, they shared a thematic link, and in the third, they were semantically unrelated. The decision to focus on these types of association stemmed from reports that the semantic organization of information facilitates ease of recall (Belacchi et al., 2011).

As mentioned in the introduction, Lucariello et al. (1992) showed, for example, that a capacity for thematic association develops early on, before the ability to form categorical links. Several models in the literature postulate that long-term memory supports information recall in the context of demanding WM tasks (Ericsson & Kintsch, 1995). In addition, as suggested by Baddeley (2000), this process could be governed by the episodic buffer.

Starting from these premises, we analyzed the influence of categorical and thematic associations on WM performance. The results on the overall sample showed that WM performance changed depending on the relationship between the words; in particular, the activation of a thematic association between words led to an increase in recall, with a greater amount of information recalled and lower number of intrusion errors. This was not the case for categorical association, in fact, the level of recall was not significantly different from the control condition (arbitrary link), and the influence of categorical association was found only on intrusion errors. Participants tended to intrude more irrelevant information in the recall with respect to the other two types of asscoiation.

Therefore, current results confirmed the facilitation due to semantic link already shown in the literature (e.g., Saint-Aubin, Ouellette, & Poirier, 2005), indicating that the effect may depend on the type of semantic link. In fact, the thematic association between words seemed to prompt a more efficient retrieval of words (Hulme, Stuart, Brown, & Morin, 2003; Stuart & Hulme, 2000). In contrast, the categorical link caused an increasing the number of memory errors, an effect typically observed in WM literature (e.g. Robert, Borella, Fagot, Lecerf & de Ribaupierre, 2009).

The results seemed to be driven by the age of participants. As the second set of analyses showed, WM performance changed depending on the relationship between the words presented, but only in the younger age group. In particular, in the younger age group, activating a thematic link between the words in a list made them easier to recall, with fewer intrusion errors, but the same did not apply to categorical links. This latter result is consistent with some previous findings showing a detrimental effect of the presence of a categorical association on recall in WM tasks (e.g., Carretti et al., 2003), especially when individual differences are considered and particularly in younger children (Mansfield, 1977). The better control of intrusion errors in the older children could be associated with the way that interference control progressively develops throughout childhood (e.g., Robert et al., 2009). In fact, interference control is an important predictor of WM capacity (e.g., Engle, 2010).

Our findings are consistent with reports that material involving semantically related lists is recalled better than unrelated material (Germano, Kinsella, Storey, Ong, & Ames, 2008), but this beneficial effect depends on the nature of the semantic organization (as already mentioned) and in part on the age group considered. In fact, our results showed that younger children were particularly sensitive to thematic links between words, and it was only in our younger group that semantic links had a significant positive influence on performance. This could be interpreted as a product of the age-related differences in the development of semantic organization (Lucariello et al., 1992); the earlier development of thematic associations, taking place before the development of categorical ones could in fact explain the advantage of semantic linking apparent in the younger age group's recall performance. However, the absence of the same effect (or in general of a better recall of semantically associated words with respect to the arbitrary ones) in older children warrants further study.

It is worth noting, however, that the effects we detected are not particulary strong. This could be due in part to the construction of the lists in the WM task. In the current task, the words designed to elicit categorical and thematic links were always placed at the end of the list. A future manipulation could place the categorical and thematic words first in the list. This could spread the activation across related words, as some previous studies have indicated (Belacchi et al., 2011; 2013). When placed in first position, the superoridinate term could act as a retrieval cue for the entire semantic network contained in long-term semantic memory (Ericsson & Kintsch, 1995). Presumably, the activation of the conceptual-superordinate node may in turn activate the complex network (Collins & Quillian, 1969) of different subordinate exemplars belonging to a given category (Heit & Barsalou, 1996). This could also explain why, compared for example to Belacchi and coauthors (2011), the effects were not particularly strong.

It may be that the automatic activation of semantic associations between words sustains information recall in WM, as suggested by various studies in the literature using WM tasks with words (Germano et al., 2008; Jefferies et al., 2004) and sentences (Belacchi et al., 2011; Kapikian & Briscoe, 2012; Osaka, Nishizaki, Komori, & Osaka, 2002). This effect, however, could be more evident only in young children, or in participants with limited WM resources (Osaka et al., 2002; Belacchi et al., 2011). As for the mechanism underlying this effect, it may be that older children or participants with high WM capacities are already using their cognitive resources effectively, performing at their best. In fact, compared to previous studies (e.g., Belacchi et al., 2011), the effects described in the present paper were probably not strong enough to activate the semantic network in these children. Whereas, when the WM system does not work at its best levels as developmental changes are in process (e.g., in younger children) semantic information could play a crucial role. In fact, it could be of a particular interest to analyze the effect of semantic manipulation in children with specific difficulties. For example, the so-called *poor comprehenders* (i.e. children with adequate reading decoding, but difficulties in the understanding of the text, per Cain & Oakhill, 2007), also have difficulties with semantic processing; the effect of semantic manipulation, to the best of our knowledge, was not studied.

To sum up, the present results confirm the importance of long-term memory in the performance of WM tasks. In this sense, referring to the Baddeley's model to the possible role of the episodic buffer as the place where LTM and WM come together. Some intriguing results emerged here regarding the effect of categorical links on recall, particularly in younger children, which contrast with previous reports (Lucariello et al., 1992; Nelson, 1996). Further studies are therefore needed to elucidate this issue, preferably involving a broad range of ages and a large number of participants (in fact we were only able to test a limited number of participants in each group), to shed more light on the interaction between information stored in LTM and WM performance. Furthermore, future studies should also consider manipulating the order of presentation of the categorical link, perhaps including it in various positions in a list to see whether this affects recall and/or the number of intrusion errors. It is worth mentioning that the effect demonstrated in the present study is not very large in terms of magnitude. This finding is in line with our expectations and with the literature. However, we believe that even small effects are valuable and can have important theoretical and practical implications.

Despite some limitations, the present report has several strengths. First, we showed that the semantic organization of the material has a valuable effect. Only a few studies have been conducted on this topic, possibly due to a problem of statistical power. In fact, the magnitude of the effect is small (in terms of effect size), and this makes it necessary to consider a large number of participants in order for results to reach an adequate statistical power. Second, we demonstrated that the effect of semantic links is not always the same; it changes with age. This finding could be relevant from a developmental standpoint. We believe that our newly-developed measure of WM is sensitive to semantic organization, as shown by results obtained in the younger child sub-sample. In fact, it would be interesting to investigate if the same effect applies to different age groups and different types of participants (for example those having difficulties in aspects of semantic processing of language).

References

Alloway, T. P., Gathercole, S. E., & Pickering, S. J. (2006). Verbal and visuospatial short-term and working memory in children: Are they separable? *Child Development*, *77*, 1698–716. doi:10.1111/j.1467-8624.2006.00968.x

Baddeley, A. D. (1966). The influence of acoustic and semantic similarity on long-term memory for word sequences. *Quarterly Journal of Experimental Psychology*, *18*, 302–309. doi:10.1080/14640746608400047

Baddeley, A. D. (1996). Exploring the central executive. *The Quarterly Journal of Experimental Psychology Section A*, *49*, 5–28. doi:10.1080/713755608

Baddeley, A. D. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences*, *4*, 417–423. doi:10.1016/S1364-6613(00)01538-2

Baddeley, A. D. (2012). Working memory: theories, models, and controversies. *Annual Review of Psychology*, *63*, 1–29. doi:10.1146/annurev-psych-120710-100422

Baddeley, A. D., & Hitch, G. J. (1974). Working Memory. In G. A. Bower (Ed.), *The Psychology of Learning and Motivation: Advances in Research and Theory* (Vol. 8, pp. 47–90). New York: Academic Press.

Baddeley, A. D., Hitch, G. J., & Allen, R. J. (2009). Working memory and binding in sentence recall. *Journal of Memory and Language*, *61*, 438–456. doi:10.1016/j.jml.2009.05.004

Bauer, P. J., & Mandler, J. M. (1989). One thing follows another: Effects of temporal structure on 1- to 2-year-olds' recall of events. *Developmental Psychology*, *25*, 197–206. doi:10.1037/0012-1649.25.2.197

Belacchi, C., Benelli, B., & Dispaldro, M. (2013). Semantic representation and verbal working memory: The impact of schematic knowledge on word recall in children at different age levels. *Bollettino Di Psicologia*, *268*, 13–28.

Belacchi, C., Benelli, B., & Pantaleone, S. (2011). The influence of categorical organization on verbal working memory. *The British Journal of Developmental Psychology*, *29*, 942–960. doi:10.1111/j.2044-835X.2011.02030.x

Benelli, B., Arcuri, L., & Lonciari, I. (1989). Gli animali sono quelli che si vedono allo zoo: Il ruolo della rappresentazione degli eventi nella formazione delle categorie superordinate. In B. Benelli (Ed.), *Lo sviluppo dei concetti nel bambino: quando Fido diventa un animale* (pp. 48–59). Firenze, Italy: Giunti O. S.

Blewitt, P., & Krackow, E. (1992). Acquiring taxonomic relations in lexical memory: The role of superordinate category labels. *Journal of Experimental Child Psychology*, *54*, 37–56. doi:10.1016/0022-0965(92)90016-Y

Blewitt, P., & Toppino, T. C. (1991). The development of taxonomic structure in lexical memory. *Journal of Experimental Child Psychology*, *51*, 296–319. doi:10.1016/0022-0965(91)90038-T

Borella, E., Carretti, B., & Pelegrina, S. (2010). The specific role of inhibition in reading comprehension in good and poor comprehenders. *Journal of Learning Disabilities*, *43*, 541–52. doi:10.1177/0022219410371676

Bower, G. H. (1970). Organizational factors in memory. *Cognitive Psychology*, *1*, 18–46. doi:10.1016/0010-0285(70)90003-4

Carretti, B., Bellina, M., & Palladino, P. (2003). Intrusioni in un compito di memoria di lavoro: è solo un effetto di categoria? [Intrusion errors in WM: Only categorical effects?]. *Giornale Italiano Di Psicologia*, *1*, 171–178. doi:10.1421/8649

Carretti, B., Cornoldi, C., De Beni, R., & Palladino, P. (2004). What happens to information to be suppressed in working-memory tasks? Short and long term effects. *The Quarterly Journal of Experimental Psychology.*, *57*, 1059–84. doi:10.1080/02724980343000684

Cermak, L. S., Butters, N., & Moreines, J. (1974). Some analyses of the verbal encoding deficit of alcoholic Korsakoff patients. *Brain and Language*, *1*, 141–150. doi:10.1016/0093-934X(74)90030-3

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.

Collins, A. M., & Quillian, M. R. (1969). Retrieval time from semantic memory. *Journal of Verbal Learning and Verbal Behavior*, *8*, 240–247. doi:10.1016/S0022-5371(69)80069-1

Cowan, N. (1995). *Attention and Memory: An Integrated Framework.* Oxford, UK: Oxford University Press, USA.

Cowan, N. (2010). The magical mystery four: How is working memory capacity limited, and why? *Current Directions in Psychological Science*, *19*, 51–57. doi:10.1177/0963721409359277

Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. Journal of Verbal Learning and Verbal Behavior, 19, 450–466. doi:10.1016/S0022-5371(80)90312-6

De Beni, R., Palladino, P., Pazzaglia, F., & Cornoldi, C. (1998). Increases in intrusion errors and working memory deficit of poor comprehenders. *The Quarterly Journal of Experimental Psychology*, *51*, 305–20. doi:10.1080/713755761

Demb, J. B., Desmond, J. E., Wagner, A. D., Vaidya, C. J., Glover, G. H., & Gabrieli, J. D. (1995). Semantic encoding and retrieval in the left inferior prefrontal cortex: a functional MRI study of task difficulty and process specificity. *The Journal of Neuroscience*, *15*, 5870–8.

Demetriou, A., Christou, C., Spanoudis, G., & Platsidou, M. (2002). The development of mental processing: Efficiency, working memory, and thinking. *Monographs of the Society for Research in Child Development*, *67*, i–viii, 1-155; discussion 156.

Demetriou, A., Spanoudis, G., & Shayer, M. (2013). Developing intelligence: Is a comprehensive theory possible? *Intelligence*, *41*, 730–731. doi:10.1016/j.intell.2013.07.017

Demetriou, A., Spanoudis, G., Shayer, M., Mouyi, A., Kazi, S., & Platsidou, M. (2013). Cycles in speed-working memory-G relations: Towards a developmental–differential theory of the mind. *Intelligence*, *41*, 34–50. doi:10.1016/j.intell.2012.10.010

Engle, R. W. (2010). Role of working-memory capacity in cognitive control. *Current Anthropology*, *51*, S17–S26. doi:10.1086/650572

Ericsson, K. A., & Kintsch, W. (1995). Long-term working memory. *Psychological Review*, *102*, 211–245. doi:10.1037/0033-295X.102.2.211

Gathercole, S. E., Pickering, S. J., Ambridge, B., & Wearing, H. (2004). The structure of working memory from 4 to 15 years of age. *Developmental Psychology*, *40*, 177–90. doi:10.1037/0012-1649.40.2.177

Germano, C., Kinsella, G. J., Storey, E., Ong, B., & Ames, D. (2008). The episodic buffer and learning in early Alzheimer’s disease. *Journal of Clinical and Experimental Neuropsychology*, *30*, 627–38. doi:10.1080/13803390701594894

Hashimoto, N., McGregor, K. K., & Graham, A. (2007). Conceptual organization at 6 and 8 years of age: Evidence from the semantic priming of object decisions. *Journal of Speech Language and Hearing Research*, *50*, 161. doi:10.1044/1092-4388(2007/014)

Heit, E., & Barsalou, L. W. (1996). The instantiation principle in natural categories. *Memory*, *4*, 413–452. doi:10.1080/096582196388915

Hulme, C., Stuart, G., Brown, G. D. A., & Morin, C. (2003). High-and low-frequency words are recalled equally well in alternating lists: Evidence for associative effects in serial recall. *Journal of Memory & Language, 49*, 500-518. doi: 10.1016/S0749-596X(03)00096-2

Jefferies, E., Lambon Ralph, M. A., & Baddeley, A. D. (2004). Automatic and controlled processing in sentence recall: The role of long-term and working memory. *Journal of Memory and Language, 51*, 623–643. doi:10.1016/j.jml.2004.07.005

Kapikian, A., & Briscoe, J. (2012). Semantic binding, not attentional control, generates coherent global structure in children's narrative memory. *Journal of Cognitive Psychology, 24*, 751–764. doi:10.1080/20445911.2012.690554

Lucariello, J., Kyratzis, A., & Nelson, K. (1992). Taxonomic knowledge: What kind and when? *Child Development*, *63*, 978. doi:10.2307/1131248

Mandler, J. M. (1978). *Categorical and Schematic Organization in Memory*. Department of Psychology, University of California, San Diego.

Mansfield, A. F. (1977). Semantic organization in the young child: Evidence for the development of semantic feature systems. *Journal of Experimental Child Psychology*, *23*, 57–77. doi:10.1016/0022-0965(77)90073-X

Marconi, L., Ott, M., Pesenti, E., Ratti, D., & Tarella, M. (1994). *Lessico elementare. Dati scolastici sull'italiano scritto e parlato dai bambini delle elementari [Basic vocabulary: Data on written and spoken Italian of children at the elementary school]*. Bologna, Italy: Il Mulino.

Mathy, F., & Feldman, J. (2012). What's magic about magic numbers? Chunking and data compression in short-term memory. *Cognition*, *122*, 346–62. doi:10.1016/j.cognition.2011.11.003

Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review*, *63*, 81–97. doi:10.1037/h0043158

Nelson, K. (1977). The syntagmatic-paradigmatic shift revisited: A review of research and theory. *Psychological Bulletin*, *84*, 93–116. doi:10.1037/0033-2909.84.1.93

Nelson, K. (1996). *Language in Cognitive Development: The Emergence of the Mediated Mind*. Cambridge, UK: Cambridge University Press.

Osaka, M., Nishizaki, Y., Komori, M., & Osaka, N. (2002). Effect of focus on verbal working memory: Critical role of the focus word in reading. *Memory & Cognition, 30*, 562–571. doi:10.3758/BF03194957

Palladino, P., Cornoldi, C., De Beni, R., & Pazzaglia, F. (2001). Working memory and updating processes in reading comprehension. *Memory & Cognition*, *29*, 344–354. doi:10.3758/BF03194929

Passolunghi, M. C., Cornoldi, C., & De Liberto, S. (1999). Working memory and intrusions of irrelevant information in a group of specific poor problem solvers. *Memory & Cognition*, *27*, 779–790. doi:10.3758/BF03198531

Robert, C., Borella, E., Fagot, D., Lecerf, T., & de Ribaupierre, A. (2009).Working memory and inhibitory control across the life span: Intrusion errors in the Reading Span Task. *Memory & Cognition, 37*, 336-345. doi:10.3758/MC.37.3.336.

Rosch, E., Mervis, C. B., Gray, W. D., Johnson, D. M., & Boyes-Braem, P. (1976). Basic objects in natural categories. *Cognitive Psychology*, *8*, 382–439. doi:10.1016/0010-0285(76)90013-X

Saint-Aubin, J., Ouellette D., & Poirier M. (2005). Semantic similarity and immediate serial recall: is there an effect on all trials? *Psychonomic Bullettin & Review, 12*,171-177. doi:

10.3758/BF03196364

Shank, R., & Abelson, R. P. (1977). *Scripts, Plans, and Understanding: An Inquiry Into Human Knowledge Structures.* Hillsdale, NJ: Erlbaum Associates.

Stuart, G., & Hulme, C. (2000). The effects of word co-occurance on short-term memory: Associative links in long-term memory affect short-term memory performance. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 26*, 796-802. doi: 10.1037/0278-7393.26.3.796

Swanson, H. L., Howard, C. B., & Sáez, L. (2006). Do different components of working memory underlie different subgroups of reading disabilities? *Journal of Learning Disabilities*, *39*, 252–269. doi:10.1177/00222194060390030501

Thurstone, L. L., & Thurstone, T. G. (1963). *Primary Mental Abilities*. Chicago, IL: Science Research.

Towse, J. N., Cowan, N., Horton, N. J., & Whytock, S. (2008). Task experience and children's working memory performance: A perspective from recall timing. *Developmental Psychology*, *44*, 695–706. doi:10.1037/0012-1649.44.3.695

Tulving, E., & Craik, F. I. M. (2000). *The Oxford handbook of memory*. Oxford, England: Oxford University Press.

Vygotskij, L. S. (1986). *Thought and Language.* Cambridge, UK: MIT Press.

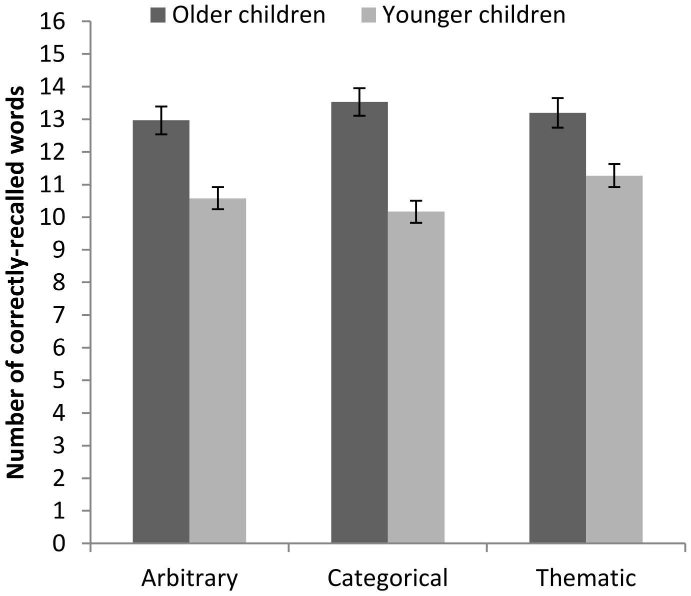

Figure 1. Differences between the two age groups in the number of words recalled correctly for the three types of semantic link. Error bars represent standard errors.

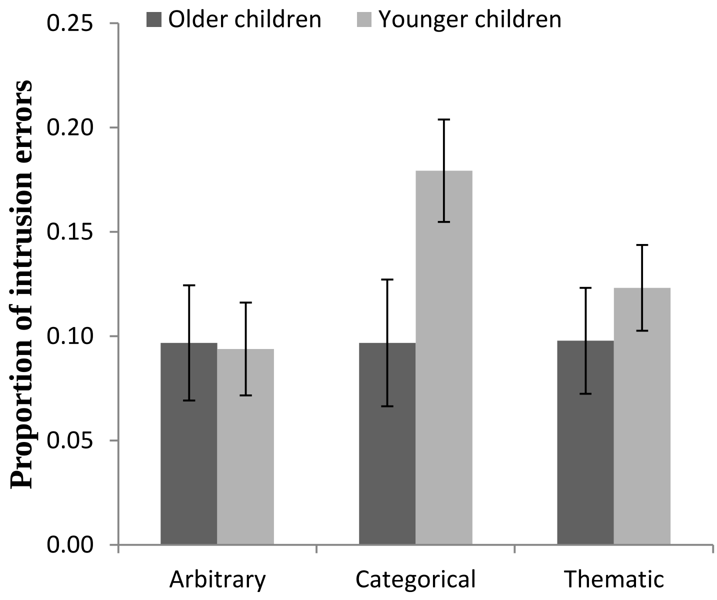

Figure 2. Differences in the proportion of intrusion errors for the three types of semantic link. Error bars represent standard errors.

Footnotes

[1] Results are very similar when including these subjects. We performed a 2 (age group [age 6-7 and 8-10 years old]) × 3 (semantic link [arbitrary, categorical, or thematic]) mixed analysis of variance (ANOVA) on the number of correctly recalled words. We found a significant main effect of age group, $F(1, 158) = 29.08$, $p < .001$, $\eta^2_p = .155$, with a medium ES, older children recalling more words than younger ones. The effect of the semantic link was not significant, $F(2, 316) = 2.96$, $p = .056$, $\eta^2_p = .018$, and the ES was small. The interaction between age group and semantic link was significant, however, $F(2, 316) = 6.18$, $p = .002$, $\eta^2_p = .038$. On post hoc analysis with Bonferroni's correction, only the younger children (6- and 7-year-olds) showed a significant difference between the thematic type of link and the other two (arbitrary, $p < .001$; categorical, $p = .006$). We performed a 2 (age group [age 6-7 and 8-10 years old]) × 3 (semantic link [arbitrary, categorical, and thematic]) mixed ANOVA on the proportion of intrusion errors. A significant main effect was found for the semantic link, $F(2, 316) = 4.21$, $p = .016$, $\eta^2 = .03$, again with a small ES, reflecting the previously-discussed results, but not for age group, $F(1, 158) = 1.55$, $p = .215$, $\eta^2 = .01$. The interaction between age group and semantic link was significant, $F(2, 316) = 4.21$, $p = .017$, $\eta^2_p = .03$, with a small ES. As concerns this interaction, the difference only emerged for the younger children, who made more intrusion errors associated with the categorical type of link than with the arbitrary ($p < .001$) or thematic ($p = .007$) links.

[2] We performed separate ANOVAs for younger and older children. We found a significant main effect of the semantic link in the younger group for both correctly recalled words, $F(2, 194) = 8.92$, $p < .001$, $\eta^2_p = .084$, and intrusion errors, $F(2, 194) = 8.06$, $p < .001$, $\eta^2_p = .077$, with moderated ESs. On the contrary, the effects in the older group were not statistically significant for both correctly recalled words, $F(2, 122) = 1.65$, $p = .196$, $\eta^2_p = .026$, and intrusion errors, $F(2, 122) = 0.002$, $p = .998$, $\eta^2_p < .000$, with small ESs.