Assessing sequential reasoning skills in typically developing children

Laura Zampini, Paola Zanchi, Chiara Suttora, Maria Spinelli, Mirco Fasolo, Nicoletta Salerni

Department of Psychology, University of Milano-Bicocca

ABSTRACT. Questo studio ha l'obiettivo di descrivere il *Sequential Reasoning Task* (*SRT*), un nuovo strumento sviluppato per valutare la capacità dei bambini di disporre degli eventi in ordine temporale. Hanno partecipato allo studio 200 bambini di età compresa fra 3 e 8 anni, a ciascuno dei quali è stata proposta individualmente una batteria di test cognitivi e linguistici. La prova SRT si rivela un valido strumento per valutare le abilità di ragionamento sequenziale: inoltre, il punteggio ottenuto dai bambini alla prova SRT risulta essere significativamente correlato con le loro competenze verbali e non-verbali.

SUMMARY. Introduction: Since serial ordering has an important role in both language development and learning abilities, the present study aims to describe a new instrument, the Sequential Reasoning Task (SRT), specifically designed to assess children's ability to place events in temporal order. Methods: Participants were 200 typically developing children, ranging from 3 to 8 years of age. Each child was individually administered a battery of cognitive and linguistic tasks. Results: The scores obtained in the SRT by children at different age levels appeared to be significantly different (except for 6- and 7-year-old children). Moreover, the scores obtained in the task were significantly related to the children's non-verbal and linguistic competence. Conclusions: The SRT appeared to be a valid instrument to assess children's sequential reasoning skills. It is engaging for children and easy to be administered also by teachers and therapists.

Keywords: *Sequential reasoning, Picture arrangement, Assessment, Language, Preschool age, School age*

INTRODUCTION

Starting from the preschool period, children have been observed to develop sequential reasoning skills (Catellani, 1991). Children younger than 3 years old have a good ability to comprehend temporal connections and to reproduce event sequences in the order in which they occur (e.g., Bauer & Thal, 1990). The ability to place events in temporal order has an important role in language development, in particular in narrative comprehension, and it is essential to construct a coherent mental representation of the events (Cain, Oakhill & Bryant, 2004; Zampini, Suttora, D'Odorico & Zanchi, 2013). For instance, in their recent study, Zampini et al. (2013) found that sequential reasoning skills, assessed by a picture arrangement task, explained part of the variance in listening text comprehension in 3-year-old children. This result was interpreted considering children's knowledge of scripts, in fact, if a child knows the order of things in real life, he/she may not only better understand how to arrange pictures, but he/she may also anticipate characters' actions in narrative texts.

Some studies found a significant relationship between language development and the ability of ordering events in children with developmental disorders. Johnels, Hagberg, Gillberg & Miniscalco (2013) showed that both temporal sequencing skills and language development were significant predictors of the ability to convey story information in the narratives of children with neurodevelopmental disorders. Moreover, Miranda, McCabe & Bliss (1998) found that children with specific language impairment (SLI) produced more narratives in which events are not ordered chronologically than typically developing children matched for age or syntactic level did.

Since serial ordering has an important role in both language development and learning abilities, the assessment of this competence in children has been frequently considered in standardised intelligence tests, as in the *Sequential Order* subtest of the Leiter-R (Roid & Miller, 1997), in the *Story Completion* subtest of the KABC-II (Kaufman & Kaufman, 2004) and in the *Picture Arrangement* subtest of the WISC-III (Wechsler, 1991), although this subtest has been removed from the most recent versions of the WISC. However, the possibility to objectively assess non-verbal serial ordering could be useful not only for clinicians (during intelligence assessment), but also for teachers, to programme targeted educational programs, and for speech and language therapists, to programme specific rehabilitation treatments. Therefore, a simple and specific instrument designed to assess children's serial order abilities could be helpful in both schools and rehabilitation services.

The aim of the study is to describe a new instrument, the *Sequential Reasoning Task* (SRT), specifically designed to assess children's ability to place events in temporal order. Descriptive data on the performance of children from 3 to 8 years of age are presented. Our hypothesis is that sequential reasoning skills gradually increase with children's chronological age and/or in the transition from kindergarten to primary school. In addition, the relationships between children's sequential reasoning skills and their cognitive and linguistic abilities are investigated. Considering the above-mentioned relationships found between the ability to order events and linguistic skills, we expected to find higher SRT scores in the children with a better linguistic competence.

METHOD

Participants in this study included 200 children, aged 3 to 7;11 years (ages are indicated in years;months), divided into five groups according to their chronological age: 3 years old (from 3 to 3;11); 4 years old (from 4 to 4;11); 5 years old (from 5 to 5;11); 6 years old (from 6 to 6;11); and 7 years old (from 7 to 7;11) (Table 1). Forty children (20 females) were included in each age group. All of the children, recruited from local kindergartens and primary schools, came from monolingual Italian speaking families. None of them were reported to have developmental problems. Parents signed a written consent form.

All of the children participated in a 45-minute test session, at their kindergarten or primary school. Each child was individually administered three different tasks assessing his/her cognitive skills: the *Raven's Coloured Progressive Matrices* (CPM) (Belacchi, Scalisi, Cannoni & Cornoldi, 2008), the *Sequential Order* subtest of the Leiter-R (Roid & Miller, 1997) and our SRT. In addition, the *Test for Receptive Grammar* (TROG-2) (Suraniti, Ferri & Neri, 2009) was administered to assess children's morphosyntactic comprehension abilities: the number of sentence blocks correctly solved (ranging from 0 to 20) was considered.

For the purposes of the present study, CPM raw score (ranging from 0 to 36) was considered as a measure of general non-verbal competence and the raw score of the

Table 1 – Participants' description for each age group

	N (females)	Chronological age (in months)		
		M	***SD***	***Range***
3 year old	40 (20)	43	3.31	36-47
4 year old	40 (20)	54	3.39	48-59
5 year old	40 (20)	66	3.44	60-71
6 year old	40 (20)	78	3.27	72-83
7 year old	40 (20)	89	3.45	84-95

Sequential Order subtest (ranging from 0 to 47) was used to assess children's ability in sequential processing. This task consists of 13 pictorial sequences, with an increasing level of complexity, in which the children are asked to identify the appropriate figures that complete the sequence from an array of options (e.g., the children are requested to order some triangles from smallest to largest in size).

Whilst the *Sequential Order* subtest gave us a measure of the children's ability to process abstract sequences, the SRT aimed to assess children's ability to process complex semantic relationships between events. Therefore, this task required the children to put some narrative sequences in the correct temporal and causal order. A pilot version of this task has been used in a previous study on preschool children (Zampini et al., 2013). Some ambiguous items of the pilot version have been modified (i.e., the items in which the percentage of errors was significantly higher) and some more complex items (i.e., 6-card stories) have been added to better assess sequential reasoning skills in school-age children. The SRT consists of 12 sets of illustrated stories, divided into 4 groups with increasing complexity level, depicted on 3, 4, 5 or 6 picture cards (examples of a 3- and a 6-card story are provided in figure 1_{ab}).

First, a 3-card story example is introduced to the child: he/she is asked to arrange 3 pictures presented in a scrambled order with the aim of creating a story. If the child is not able to arrange the pictures correctly, then the examiner demonstrates the solution. After the example, all of the stories are presented to the child in a fixed order, starting with the shorter ones (depicted on 3 cards) and moving to the longer levels of 4, 5 and 6 pictures. To increase the task complexity, the 6-card stories include a change in the story's scenery (e.g., in the example in figure 1b, the first scenes are located in a garden, whereas the last scenes are located in a bathroom). For each set, the cards are provided in a fixed scrambled order (i.e., the same for each child) and the child is asked to arrange them with the aim of creating a story (the order provided for each set is reported in Appendix). If the child is not able to arrange at least one story in a certain level, task administration is stopped. A child is assigned 3 points for each 3-card set arranged correctly, 4 points for each 4-card set, 5 points for each 5-card set and 6 points for each 6-card set. No points are assigned for picture sets incorrectly arranged. The total raw score (ranging from 0 to 54) is computed by adding the scores of all sets, with the exclusion of the example.

RESULTS

The SRT shows high internal consistency (Cronbach's Alpha = .925). Descriptive statistics for the cognitive and linguistic tasks administered to the children are reported in Table 2.

To analyse the differences in narrative sequential reasoning among children at different ages, univariate ANOVA was conducted. The scores obtained in the SRT by

Figure 1 – Example of a 3-picture (a) and a 6-picture (b) story in the SRT

Note. The original pictures are coloured.

Table 2 – Descriptive statistics for cognitive and linguistic tasks

	CPM			Sequential Order			SRT			TROG-2		
	M	***SD***	***Range***	***M***	***SD***	***Range***	***M***	***SD***	***Range***	***M***	***SD***	***Range***
3 year old	10.30	2.72	6-16	4.05	2.28	0-9	3.45	4.06	0-13	1.40	1.37	0-4
4 year old	14.65	3.45	6-26	5.88	4.65	0-24	12.48	14.51	0-45	4.88	3.04	0-13
5 year old	17.05	5.03	11-31	8.75	5.46	0-26	26.78	16.40	0-54	5.85	3.54	1-16
6 year old	20.80	4.59	14-31	18.65	7.67	4-38	43.23	10.16	6-54	11.38	4.58	2-20
7 year old	24.18	4.60	12-32	23.48	8.09	7-42	43.90	6.32	28-54	12.90	4.50	3-20

children at different age levels appeared to be significantly different ($F_{(4, 195)} = 102.46$; $p<.001$; $\eta^2 = .20$). Bonferroni post-hoc analysis showed that the performance of the 3-year-old children was significantly different from the performance of the children in all of the other age groups (all $p<.01$). The same result was found for the 4-year-old children (all $p<.01$) and the 5-year-old children (all $p<.001$). However, no significant differences were found in the scores obtained by 6- and 7-year-old children ($p>.05$). The 10th, 25th and 50th percentiles are reported for each age group in Table 3.

The children's performance on the SRT was significantly related to both cognitive and linguistics skills. As shown in Table 4, Pearson's *r* partial correlation, controlling for children's age, between the children's general non-verbal intelligence (CPM) and the scores obtained on the SRT was statistically significant. The partial correlation, controlling for age, between the scores obtained on the *Sequential Order* subtest and those obtained on the SRT allows to determine the concurrent validity of the SRT as an instrument to assess children's sequential reasoning competence.

Moreover, partial correlations, controlling for age and CPM, were computed between the scores obtained on the SRT and those obtained on the TROG-2 to verify the assumption of the existence of a specific relationship between narrative sequential reasoning and language development. The analysis showed that children's morphosyntactic comprehension appeared to be significantly related to their ability to put events in the correct order, independent of their age and cognitive level.

Table 3 – Percentiles on the SRT

	10th percentile	**25th percentile**	**50th percentile**
3 year old	0	0	3
4 year old	0	0	6
5 year old	3	10	29
6 year old	34	39	45
7 year old	34	40	44

Table 4 – Pearson's r partial correlations between the scores obtained on the SRT and children's cognitive and linguistic skills

	CPM[1]		**Sequential Order**[1]		**TROG-2**[2]	
	r	*p*	*r*	*p*	*r*	*p*
SRT	.302	<.001	.324	<.001	.345	<.001

Note. [1] Controlling for children's age; [2] Controlling for children's age and CPM scores.

DISCUSSION

The SRT appeared to be a valid instrument to assess children's ability to use sequential reasoning. It is engaging for children and can be administered also by teachers and therapists, because it does not require a qualification level, as intelligence tests do. Therefore, this instrument could be very helpful in both educational and clinical practice. It is possible to administer the task to children from 3 years of age. However, it should be noted that more than 25% of 3- and 4-year-old children were not able to correctly arrange any card set. Therefore, a total task failure (i.e., the inability to solve any item) in these age ranges could not be considered as a marker of a clinical condition. In contrast, the ability to correctly order some sequences in 3- and 4-year-old children can be considered a strength.

No statistically significant differences were found in the scores obtained at the SRT by 6- and 7-year-old children (although ranges are quite different). In school-age children the performance in the SRT does not seem to be related to their chronological age, in fact the percentiles of 6- and 7-year-old children are very similar. Contrary to our hypothesis, the increasing in children's sequential reasoning skills is not gradual. In fact, looking at raw scores, it seems that there is a gap between preschool- and school-age children in this competence. It has to be noted that a similar pattern has been found in the *Sequential Order* scores. Both these results could be related to the beginning of reading and writing learning (i.e., when children are 6-year-old in Italy) that requires and trains children's sequential skills.

Our hypothesis of a relationship between the scores obtained at the SRT and children's linguistic skills has been confirmed: we found a significant correlation between the ability to place events in order and language development, independent of children's age and cognitive level. This result supports the findings of Zampini et al. (2013) who demonstrated the existence of an association between children's sequential reasoning skills and their narrative text comprehension. A possible interpretation of that association was that both the arrangement of a series of pictures and text comprehension require children to infer the entire situation from an analysis of single elements (i.e., pictures or sentences). The same interpretation could explain the association between sequential reasoning skills and morphosyntactic comprehension found in the present study: a child should infer the meaning of a sentence from an analysis of the single words. In addition, we have to consider that processing word order is a fundamental ability to comprehend complex syntactic sentences.

Limits and future directions

The cross-sectional nature of the study does not allow us to establish the direction of the association between linguistic abilities and sequential order: we do not know if morphosyntactic comprehension influences sequential reasoning skills or if the opposite is true. It is also possible that this relationship could be mediated by a third latent variable, such as children's verbal intelligence. Future studies will investigate this relationship with a longitudinal design, to clarify if sequential reasoning skills could be considered as a predictor of language development.

Moreover, future studies will investigate the association between the ability to arrange pictures and morphosyntactic comprehension in children with SLI to verify the role of sequential reasoning skills in language disorders.

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APPENDIX

Initial scrambled order provided for each card set

3-card sets	Set 1: 2 1 3	Set 2: 2 1 3	Set 3: 3 1 2
4-card sets	Set 4: 3 2 4 1	Set 5: 4 2 1 3	Set 6: 3 1 2 4
5-card sets	Set 7: 4 2 5 3 1	Set 8: 5 3 4 2 1	Set 9: 4 2 1 5 3
6-card sets	Set 10: 5 4 3 1 6 2	Set 11: 6 1 4 3 2 5	Set 12: 5 1 3 2 6 4