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Teachers' report of sense of time in kindergarten predicts children's time-processing skills in first grade

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The main aim of this longitudinal study was to evaluate if a questionnaire measuring the sense of time, filled in by teachers and parents in the last year of kindergarten, was able to predict children's time-processing skills at the end of 1st grade. The sample included 131 children (initial mean age = 4.77 ± 0.29 years) tested three times in a 2-year period with tasks of time reproduction, time discrimination, and comparison of durations. One of their parents and teachers filled in a questionnaire about children's sense of time both in kindergarten and 1st grade. The teacher version of the questionnaire administered in kindergarten was able to predict most of the time-processing tasks at the end of 1st grade. The parent version of the questionnaire was not able to predict children's performance in these tasks. Different developmental trajectories of time reproduction and time discrimination were observed. This study supports the role of preschool teachers as skilled evaluators of children's time-processing skills.

Keywords: Time-processing skills; Sense of time; Teacher's questionnaire; Longitudinal study; Children.

The capability of perceiving and processing time, definable as a sense of time, is a complex function in human beings. Individuals from childhood rely on this skill for tracking temporal durations of inner and outer events, allowing the elaboration of a sense of their own story and efficient interaction with each other and with the environment. Considering the extensive role of time-processing skills, difficulties in this area could impair many functions, such as daily school-home routines, learning activities, and social relations. To allow early identification of difficulties in time-processing and a timed intervention, we need valid and practical instruments for assessing time-related abilities in young children, in particular those that they need in their everyday contexts (e.g., time management, time orientation, use of time-related words); in the present work, according with past studies (Forman, 2015), this is defined as 'sense of time'. The present study aims at investigating the capability of the 'Sense of time questionnaire' (Tobia et al., 2018), a proxy questionnaire for parents and teachers assessing children's time-related skills, of predicting children's actual time-processing skills after 2 years.

Time-processing skills in young children

From birth, babies can learn the temporal structure of events and are able to notice temporal alterations (Brannon et al., 2004). For example, van Marle and Wynn (2005) suggest that 6-month-old children have the ability of representing and discriminating the duration of stimuli within a 2–5 second range. This result was replicated by Brannon et al. (2007) who also suggested that 6-month children failed to discriminate a 2:3 ratio in durations, whereas 10-month children accomplished the task properly. Those precocious time capacities keep improving during development until early adulthood (Droit-Volet, 2016; Odic, 2018) for the influence of factors like brain maturation and experience of temporal regularities of events. Furthermore, time information processing models demonstrate the impact of general

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cognitive skills such as memory, attention, and executive functions (Droit-Volet, 2016).

Studies have shown significant changes in children's time-processing abilities between the preschool and school periods, due mainly to neuropsychological development. Droit-Volet and Zélanti (2013) administered a temporal bisection task to preschoolers and school-aged children, observing that the temporal sensitivity increased between the ages of 3 and 8 years. Then, depending on the experimental condition, they reached an adult-like performance between 8 and 10 years old. Also, significant changes between 5 and 7 years old have been observed with time reproduction and discrimination tasks (Hallez et al., 2019; Odic, 2018). Importantly, age-related differences in time processing were observed as a function of the temporal task used (Droit-Volet, 2016), highlighting the importance of using multiple measures of it.

Investigating time-processing skills in children could be particularly important, considering the increasing evidence on the relevant role played by time-related deficits in some neurodevelopmental disorders, such as attention deficit hyperactivity disorder (ADHD; Ptacek et al., 2019) and developmental dyscalculia (Moll et al., 2016). Considering this last disorder, it should be mentioned that there is a significant association between time and numbers: for example, math abilities correlate with approximate time precision at the beginning of primary school (Odic et al., 2016) and both time and numbers can be represented spatially (Coull & Droit-Volet, 2018). Further support for the association between numbers and time came from a study on preschoolers with difficulties in numeracy (Tobia et al., 2018), which also showed weaknesses in sense of time as assessed by parents and teachers, in time reproduction and discrimination. The relationship between time and number processing is important also for the role that number-based strategies (e.g., counting) could have in supporting time estimation (Clément & Droit-Volet, 2006); coherently, poor abilities in time-processing could be a consequence of numerical deficits (Cappelletti et al., 2011). Considering that children usually start their formal education in math at the beginning of primary school, this new knowledge could support and/or change children's performance in time-processing tasks, compared with preschool years. This could partially explain, together with neuropsychological improvements (Droit-Volet, 2016), the changes observed in time processing in the passage from preschool to primary school.

Assessment of time-related skills in developmental age

The ability to process time includes, on one side, skills related to reproduction, discrimination, and estimation of durations and, on the other side, everyday life skills related to time management and a subjective sense of time. Considering the first group of variables, the present study will measure two skills: time reproduction (i.e., reproduce a presented duration, for example, pressing a button; Moll et al., 2016) and time discrimination (i.e., indicate which of two stimuli presented is the longest or shortest; Tobia et al., 2018). Such tasks must be considered explicit since the abilities involved are directly judged according to the subject's performance (Coull & Droit-Volet, 2018). An alternative way to investigate explicit time-related skills, in particular the areas of sense of time, is by using questionnaires administered to children themselves, their parents, and/or their teachers (e.g., Rossello & Servera, 2015). This can be considered as an explicit way to measure time-related skills since they are directly judged by the informants. Using questionnaires filled in by parents or teachers is fundamental when evaluating preschoolers because they are still not able to report their own skills through self-reports (Eiser & Morse, 2001). However, to assess the validity of these questionnaires, the congruence with children's performance in behavioural tasks should be considered, and it has been rarely done in the past. An exception is a work that analysed the capability of the 'Sense of time questionnaire' (Tobia et al., 2019), a questionnaire assessing children's time-related skills via proxy reports (parents and teachers), of predicting preschoolers' performance in time discrimination and time reproduction. The score of the teacher's version of the questionnaire predicted children's performance in time-processing concurrently as well as 7 months later, whereas questionnaires filled in by parents were not significantly related to the experimental observations. Also, the sense of time assessed by teachers predicted time discrimination better than time reproduction (Tobia et al., 2019). This result suggests a link between the sense of time assessed by close adults (particularly teachers) and children's processing of durations, at least within a brief (7-month) time frame in preschool years. However, to consider this instrument useful as an early detector of future difficulties or strengths in the time-processing domain, it would be important to investigate if the predicting power of the questionnaires administered in preschool can still be found in the following years, when children change their school and teachers, as well as improve their cognitive general (e.g., executive functions) and specific (e.g., numerical) skills that impact on time processing (Droit-Volet, 2016; Odic et al., 2016).

The present study

The passage from preschool to primary school represents the passage from learning through playing to formal teaching. Children in 1st grade receive formal schooling in literacy, as well as in the use of numbers and calculation. Considering the importance of numbers in

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time-related tasks, new skills learned in 1st grade could importantly change children's time-processing skills; for example, some children have been shown to use spontaneous use of counting for tracking time from 7 years of age (Clément & Droit-Volet, 2006). Also, specifically for the Italian context, some organisational features of primary school can, at least partially, impact children's time-related abilities: children begin to have a precise weekly schedule defining how many hours they will spend doing each specific subject each day, and the time spent with each teacher. Finally, children's performance in time-processing tasks changes in accordance with their attentional and executive function skills, which improve in the years of primary school (Droit-Volet, 2016).

The main aim of this study was to assess if a questionnaire measuring the sense of time administered to teachers and parents at the beginning of the last year of kindergarten—that in Italy lasts 3 years—can predict children's time-processing skills at the end of 1st grade. Despite the teacher version of this questionnaire was able to predict children's time-processing skills from the beginning (mean age = 4.78 years) to the end (mean age = 5.36 years) of the last year of kindergarten (Tobia et al., 2019), this association could change after a year of formal schooling, considering that children's new numeracy (e.g., use of counting; Droit-Volet, 2016) and time-related (e.g., knowledge of formal timing symbols; Hamamouche & Cordes, 2020) skills could modify the strategies used to respond to the time-processing tasks, and the improvement of attentional skills, as well as executive resources, could importantly change their time-processing skills (Droit-Volet, 2016). Despite these changes in 1st graders, we expect their time-processing skills to be significantly predicted by the teacher version of the Sense of time questionnaire, but not by the parent version, as happened in the past shorter longitudinal study (Tobia et al., 2019); this would be also in line with the weaknesses usually identified in parent reports (e.g., social desirability, scarce objectivity; De Los Reyes & Kadzin, 2005).

Furthermore, the changes in children's performance in time reproduction and time discrimination from the last year of kindergarten to the end of 1st grade will be analysed, expecting a global improvement in time-processing tasks from preschool to the 1st grade, in line with previous research showing changes in these skills at least until 8–10 years of age (Droit-Volet & Zélanti, 2013).

Results of this study, related to the validity of the point of view of parents and teachers in assessing and predicting children's time-related skills, and to the development of time reproduction and discrimination skills in the passage from preschool to primary school, will offer new knowledge potentially useful for the early identification of time-related difficulties in young children, which characterise different neurodevelopmental disorders (e.g., ADHD).

METHOD

Participants

The sample included 131 children (T1 mean age = 4.77 ± 0.29 years; 46.6% females) tested three times, namely two times in kindergarten (see Tobia et al., 2019; mean age T2 = 5.34 ± 0.29 years) and one time at the end of 1st grade (mean age T3 = 6.78 ± 0.27 years). The 27.5% of participants had Italian as their second language but they were schooled in Italy for at least 2 years at the time of T1. A total of 13 different first languages were represented; the most spoken first languages were Arabic (31.7% of bilinguals) and Spanish (26.8%). Six kindergartens and 7 primary schools in Northern Italy were involved, for a total of 29 teachers in kindergarten and 31 in primary school.

According to preschool teachers' reports, none of the participating children had a diagnosis of neurodevelopmental disorders; furthermore, none of the children showed a deficit in an IQ measure (nonverbal reasoning of the WPPSI-III; Wechsler, 2002), with all children having a scaled score ≥4. Socioeconomic status assessed by mothers' and fathers' education, was diverse: 23.6% of mothers and 32.3% of fathers had less than a high school diploma, 48.8% of mothers and 50% of fathers had a high school diploma, and 27.6% of mothers and 17.7% of fathers had a graduate or postgraduate degree.

Informed consent was obtained from all parents of the children included in the study; assent was obtained from children. Ethical approval was obtained from the University of Milan-Bicocca's ethics committee.

Materials

This study used a multi-informant and multi-method approach, collecting information from parents, teachers, and children themselves and administering questionnaires as well as cognitive tasks. All the materials were administered in Italian.

Sense of time questionnaire (parent and teacher versions)

A specific proxy-report questionnaire for parents and teachers was used to assess the children's sense of time (Tobia et al., 2018; Appendix A). This is a 4-point Likert questionnaire, ranging from 'Never' (0) to 'Very often' (3) with higher scores indicating better performance, and it is composed of 13 items. Nine of them investigate children's skills and time-related habits (e.g., Item 3) and their use and comprehension of temporal words (e.g., Item 8); the other 4 items are fillers used to sidestep the purpose of the questionnaire. A total score, represented by the mean of the responses to the 9 items, was calculated.

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Cronbach's alpha values for the sense of time scale, assessed for the present sample, were $\alpha = .90$ (T1) and $\alpha = .93$ (T3) for teachers and $\alpha = .85$ (T1) and $\alpha = .86$ (T3) for parents. Goodness-of-fit indices for the longitudinal invariance models of the scale items (Liu et al., 2017) were the following, respectively, for the teacher and parent versions: RMSEA = 0.116/0.087, 90% confidence interval 0.103–0.129/0.073–0.101, CFI = 0.982/0.953, TLI = 0.983/0.955, SRMR = 0.105/0.096.

Comparison of events' durations

A specific interview about children's daily time has been created to investigate the ability of children in evaluating the duration of events. This interview is composed of 10 items: 2 practice and 8 test items. The experimenter showed the child two images representing daily activities (e.g., brushing teeth, getting dressed) and asked him/her which of the two actions takes more time to be accomplished (e.g., 'It takes you longer to watch a cartoon or to put on your sweater?'). Scores ranged from 0 to 8 and the reliability value was $\alpha = .71$.

Nonverbal reasoning (WPPSI-III; Wechsler, 2002)

Nonverbal reasoning was assessed with the logical matrices subtest from the WPPSI-III standardised intelligence battery. The experimenter showed a partially filled grid and asked the child to indicate, among different drawings, which one was the correct one to insert in the matrix. The maximum score was 29. Raw scores were converted to scaled scores ($M = 10$, $SD = 3$) according to the test's Italian norms.

Time reproduction

In this task, children had to replicate the duration of the stimulus seen, namely a light bulb turning on for the target duration and then turning off. The children were exposed to visual stimuli presented on the screen for 0.5, 1, 3, or 5 s. First, they were administered three practice trials in which they had to learn how to perform the task: children had to turn on a light bulb for the same duration observed by holding down the spacebar (Moll et al., 2016). The experimental session was composed of 12 test trials, each presented three times; the same target duration was never presented two times in succession. Given that the non-decision portion of simple RTs is ~100 ms (Luce, 1986), all durations of <100 ms (1.35% of the total trials) were discarded as anticipatory errors. Then, when children reproduced a duration longer than 15 s (1.12% of the total trials), representing three times the maximum target duration (i.e., 5 s; Fortin et al., 2009), this reproduction was considered an outlier and eliminated. Each duration reproduced by children was recorded and a percentage of error for each duration was calculated. Finally, two scores were calculated on these percentages: (a) a systematic error represented by the difference between the child's reproduced duration and the duration for each target interval (allowing to know if the child globally overestimates or underestimates the durations) and (b) an absolute error which is the mean of the percentages of error not considering if they were under- or over-estimations, therefore using only the value of the percentage and not the plus or minus sign.

Time discrimination

In this task, children had to identify the longest or shortest of two sounds different only in duration (both of them had a sine wave, 400 Hz). Subjects were sitting in front of a screen with headphones, and they used two buttons (left with 'w' and right with 'p') for giving their answer. The trial was organised in the following way: first, children saw a drawing of an animal wearing headphones and at the same time they listened to a sound for the first target time. Then, after a 500 ms pause with a blank screen, they saw a new animal and listened to a different sound (second target). In the last phase, subjects saw both animals on the two sides of the screen and had to identify the shortest or the longest sound by pressing the respective button. Half of the participants, selected randomly, had to recognise the shortest sound, while the other half had to identify the longest one. After practicing with three trials, children were exposed to 36 experimental trials organised in two sessions of 18 trials with a pause in the middle. Stimuli's duration was between 0.3 and 4.5 s and the couples of sounds were in relationship 1:3, 1:2, or 2:3. For half of the trials, the right answer was on the right of the screen, and for the remaining trials, it was on the left. The number of correct answers and the reaction times (RTs) only for these correct trials were considered for the present study. Responses given in <200 ms (0.45% of the total trials), as well as responses that fell outside the within-subject mean RT of $\pm 2SD$ (5.29% of the total trials), were considered outliers and removed (Berger & Kiefer, 2021).

Procedures

The 2-years longitudinal design applied to this study was organised in three testing times: the beginning (Time 1; T1) and the end (Time 2; T2) of the last year of kindergarten and the end of the 1st grade (Time 3; T3). The parents' and teachers' versions of the Sense of time questionnaire were administered at Times 1 and 3. At all testing points (T1, T2, T3) time reproduction and time

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discrimination tasks were administered to children in an individual session taking place in a quiet room at their school. At T3, children were also administered the task measuring their ability to compare the duration of events. Examiners were graduate trainees in psychology and all the procedures were supervised by a post-doc.

Statistical analysis

Preliminary analysis includes a series of independent sample *t*-tests with a Bonferroni correction for multiple comparisons for investigating gender differences across all the variables considered and correlations between Nonverbal IQ and the other study's variables.

To investigate the longitudinal ability of the Sense of time questionnaires to predict time-processing skills, a structural equation model was run by applying the maximum-likelihood estimator. The sense of time scores obtained from parents and teachers at T1 were inserted into the model as predictors, whereas the Sense of time questionnaire administered to parents and teachers at T3, time discrimination, absolute errors of time reproduction for short (500 ms) and long (mean of 1000, 3000, and 5000 ms) durations, and the score at the comparison of duration task, measured at T3, were the dependent variables. All the variables included in the models were observed variables, except for time discrimination, which was obtained by a confirmatory factor analysis run on accuracy and RTs. The model also included a correlational link between the two questionnaire scores at T1. Multiple indices were used to evaluate the model fit: the Chi Square Test of Model Fit, Root Mean Square Error of Approximation (RMSEA), the Comparative Fit Index (CFI), the Tucker-Lewis Index (TLI), and the Standardised Root-Mean-square Residual (SRMR). RMSEA values ≤ 0.06, CFIs and TLIs ≥ 0.90, and an SRMR ≤ 0.08 suggest an acceptable model fit (Hu & Bentler, 1999).

To analyse the development of time-processing skills between T1 and T3, a repeated-measure MANOVA was run on the systematic errors observed for the four durations in the time reproduction task at T1, T2, and T3. Furthermore, two repeated-measure ANOVAs were run on measures of accuracy and RTs in time discrimination to assess changes between T1 and T3 in these variables.

RESULTS

Table 1 reports the descriptives for all the variables analysed at T1, T2, and T3. The series of independent sample *t*-tests with Bonferroni correction (corrected threshold: $p < .0018$) showed non-significant differences between males and females for all the variables considered, ts(129) = −2.088 to 2.985, ps = .003–.893. Also, the analysis of correlations between Nonverbal IQ and the other study's variables revealed only a few (4 out of 27) and weak ($r < .300$; Schober et al., 2018) significant correlations, not surviving a Bonferroni correction (corrected threshold: $p < .0018$), rs = −.123 to .264, ps = .002–.954. These variables were not further considered in the analyses.

The predictive power of the sense of time questionnaire

Figure 1 shows the significant standardised parameters for the model tested. Sense of time as reported by teachers in kindergarten significantly predicted all the dependent variables at the end of primary school, except for the reproduction of long durations. As for the Sense of time reported by parents at T1, it predicted only the Sense of time questionnaires scores at T3, for both parents and teachers, but not the children's performance at the behavioural tasks. The model showed good fit indices: model $\chi^2(6) = 7.746$ with $p = .257$, RMSEA = 0.047, 90% confidence interval 0.000–0.129, CFI = 0.993, TLI = 0.959, SRMR = 0.030. The proportion of explained variance was 46 and 23%, respectively, for the Sense of time questionnaire scores administered at T3 to parents and teachers, 20% for time discrimination, 7% for time reproduction of 500 ms, 4% for time reproduction of longer durations, and 9% for the comparison of durations.

Development of time-processing skills from kindergarten to 1st grade

The development of time-processing skills between T1, T2, and T3 was analysed. The repeated measure MANOVA run on the time reproduction scores showed a significant multivariate effect of Testing time, $F(2,122) = 10.599$, $p < .001$, $\eta^2 = .148$, Duration, $F(3,121) = 44.972$, $p < .001$, $\eta^2 = .527$, and a significant interaction Testing time*Duration, $F(6,118) = 8.027$, $p < .001$, $\eta^2 = .290$. As represented in Figure 2, children showed increased accuracy in estimating durations of 500 and 1000 ms from T1 and T2 ($p < .001$), but not from T2 and T3. On the contrary, for the longest duration considered (5000 ms), a stable time reproduction ability was observed from T1 to T2, but an improvement, in terms of lower underestimation, was observed in 1st grade ($p < .001$). For the 3000 ms duration, children's performance at T3 was better than their performance at T2 ($p = .002$), but similar to the one at T1, revealing a non-linear pattern of change.

Then, the longitudinal performance at the time discrimination task was investigated. For the accuracy score, a significant multivariate effect of Testing time was found, $F(2,123) = 61.239$, $p < .001$, $\eta^2 = .499$: children had a similar score at T1 and T2, but a significant improvement was shown at T3 ($p < .001$). As for RTs,

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TABLE 1
Descriptive statistics for the questionnaires and the tasks administered

		Mean (SD)	*Range*	*Skewness* (*SE* = .212)	*Kurtosis* (*SE* = .420)
Time 1	Sense of Time Questionnaire-parents	2.00 (0.52)	0.78–3.00	−.142	−.861
	Sense of Time Questionnaire-teachers	1.76 (0.62)	0.22–2.78	−.369	−.293
	Time reproduction absolute error for 500 ms (%)	177.18 (204.60)	14.80–921, 27	1.635	2.078
	For long durations (%)	103.62 (71.56)	17.08–376.99	1.531	2.105
	Time reproduction systematic error for 500 ms (%)	136.14 (223.94)	−78.80 to 921.27	1.446	1.459
	1000 ms (%)	55.81 (143.26)	−85.40 to 622.90	1.701	2.822
	3000 ms (%)	−25.90 (56.13)	−93.27 to 192.00	1.579	3.308
	5000 ms (%)	−40.63 (38.69)	−96.32 to 105.10	.849	.722
	Time discrimination accuracy	23.15 (5.82)	7–36	−.321	−.054
	Time discrimination mean RT (ms)	2605 (1312)	860–9529	2.529	9.772
Time 2	Time reproduction systematic error for 500 ms (%)	43.71 (140.54)	−72.60 to 1046	4.287	24.362
	1000 ms (%)	1.65 (56.56)	−83.30 to 292.70	2.291	8.979
	3000 ms (%)	−32.91 (33.30)	−94.70 to 105.23	.921	2.266
	5000 ms (%)	−38.11 (28.79)	−97.18 to 39.50	.235	.045
	Time discrimination accuracy	23.18 (6.07)	7–34	−.549	−.581
	Time discrimination mean RT (ms)	2341 (1014)	609–6067	1.280	2.047
Time 3	Sense of Time Questionnaire-parents	2.23 (0.51)	0.75–3.00	−.513	−.413
	Sense of Time Questionnaire-teachers	2.04 (0.70)	0.33–3.00	−.498	−.763
	Time reproduction absolute error for 500 ms (%)	64.56 (97.76)	5.60–689.80	4.583	24.726
	for long durations (%)	40.56 (25.64)	6.03–192.39	3.176	13.541
	Time reproduction systematic error for 500 ms (%)	24.83 (107.43)	−60.60 to 689.80	4.157	21.327
	1000 ms (%)	8.24 (71.09)	−72.00 to 463.80	3.968	19.812
	3000 ms (%)	−21.78 (28.92)	−80.90 to 120.80	1.281	4.051
	5000 ms (%)	−28.02 (25.00)	−81.72 to 51.24	.434	.238
	Time discrimination accuracy	28.69 (5.35)	6–36	−1.866	4.625
	Time discrimination mean RT (ms)	1741 (673)	549–4300	1.091	2.407
	Comparison of durations	6.92 (1.58)	1–8	−1.712	2.441

a significant multivariate effect of Testing time was again observed, $F(2,123) = 51.207$, $p < .001$, $\eta^2 = .454$, with children becoming gradually faster from T1 to T2 ($p = .017$) and from T2 to T3 ($p < .001$).

Finally, two repeated measures *t*-tests investigated the differences between T1 and T3 in the Sense of time scores, finding significant improvements both for the parent, $t(126) = -6.009$, $p < .001$, $d = .45$, and the teacher, $t(130) = -4.632$, $p < .001$, $d = .42$, versions.

DISCUSSION

The main aim of this research was to assess the validity of a questionnaire measuring children's sense of time from the point of view of their teachers and parents, evaluating if scores obtained in the last year of kindergarten were able to predict children's time-processing skills measured with behavioural tasks in 1st grade. The teacher version of this questionnaire was able to predict time reproduction and time discrimination from the beginning to the end of the last year of kindergarten (Tobia et al., 2019) but, considering the improvement of children's abilities in numeracy (Clément & Droit-Volet, 2006) and in time-related skills (Hamamouche & Cordes, 2020), this association could change during development. The present study had the secondary aim of investigating the changes in children's performance in time reproduction and time discrimination from the last year of kindergarten to the end of 1st grade. Both these pieces of evidence could play a role in the early assessment of time-related difficulties, which characterise many neurodevelopmental disorders (e.g., Ptacek et al., 2019).

Predicting time-processing skills with a proxy-report questionnaire

The analysis of the predictive power of the sense of time questionnaires revealed, as expected, a significant role of the teacher version in predicting most of the time-processing tasks administered at the end of 1st grade, namely time discrimination, time reproduction of short durations (500 ms) and comparison of durations. Also, the sense of time questionnaire filled in by teachers at T1 predicted both the scores at the same questionnaire filled in by parents and (different) teachers in 1st grade. On the contrary, the parents' version predicted only the response to the same questionnaire 2 years later, but none of the time-processing tasks administered.

This evidence further endorses Tobia et al. (2019) result that the Sense of time questionnaire filled in by

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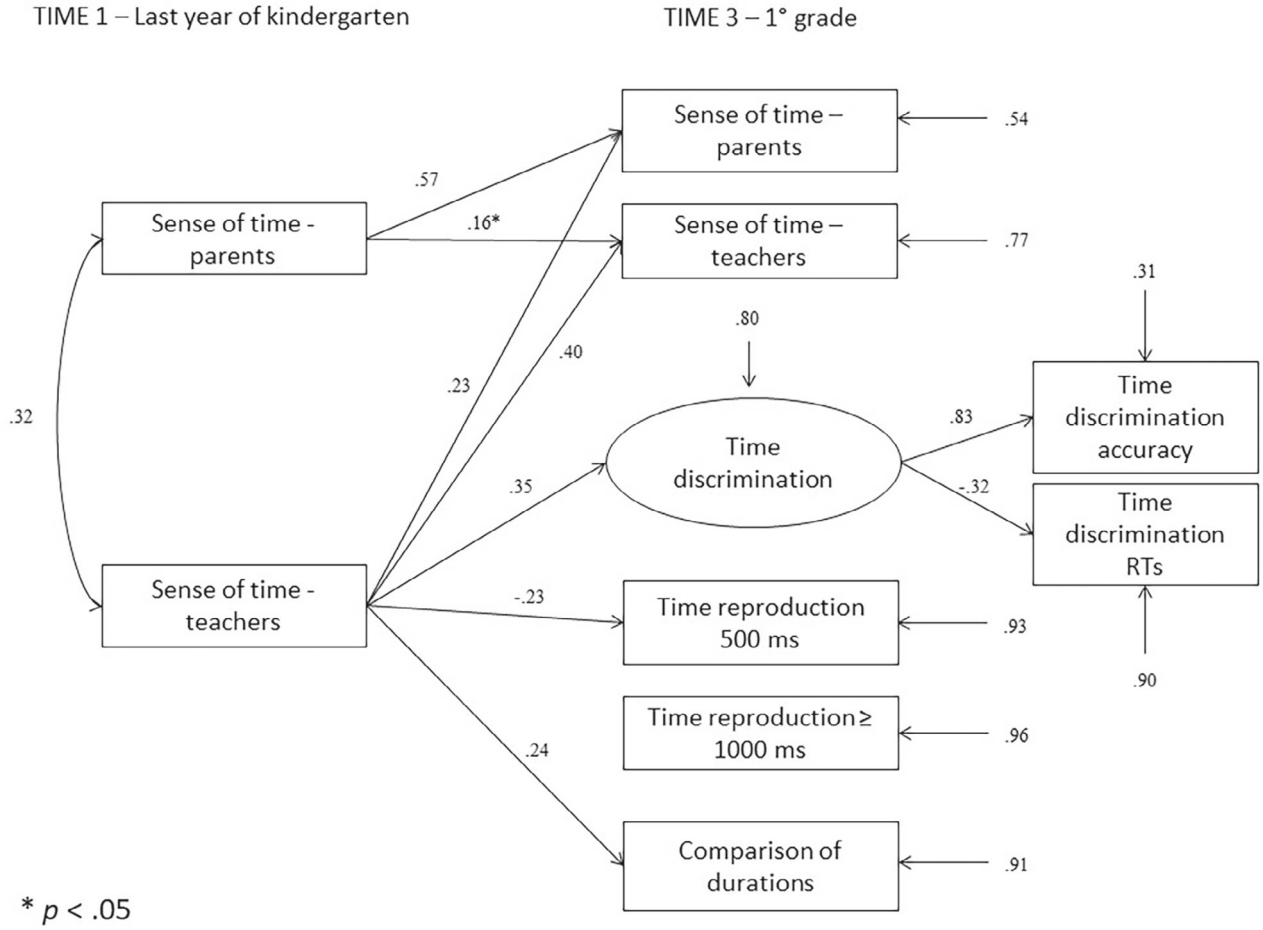

Figure 1. Model longitudinally predicting time processing skills and sense of time in 1st grade. Plain arrows represent significant relationships at $p \leq .01$. The arrows pointing to the dependent variables represent their residual variances. *$p < .05$.

teachers is a valid instrument for assessing and predicting young children's time-processing abilities. In particular, extending the longitudinal investigation to the end of 1st grade and including the assessment of an additional task (comparison of durations) and of an additional proxy-evaluation of time-related skills (by primary school teachers), the present study supports the validity of the Sense of time questionnaire-teacher for investigating time-processing skills in young children. This ability to observe and evaluate children's skills could be attributed to the great variability of children that teachers see and to their possibility of comparing them with their peers. Furthermore, teachers engage their pupils in time-limited activities, as well as tasks that could include time-related concepts (e.g., storytelling, learning the school-day timeline), and these situations could be an opportunity for them to get an idea of their pupils' time-related skills. This is a clear exemplification of what has been suggested by De Los Reyes and Kadzin (2005): the level of discrepancy among characteristics as observed by different raters may vary according to the different life contexts in which a certain trait or skill is measured.

According to the same argument, it can be hypothesized why questionnaires filled in by parents are not good predictors of time-processing tasks. First, there is an intrinsic limit to self-administered questionnaires to parents due to social desirability and objectivity (De Los Reyes & Kadzin, 2005). Second, there is great variability in response, therefore each parent could overestimate or underestimate the frequency with which children emit certain behaviours. The assessments provided by the teachers, on the other hand, have greater internal stability because they are made by experts in children's development. The school context enhances the possibility to observe several levels of expression of these abilities in a large number of children as related to different tasks. In this regard, a reflection should be made on the items included in the questionnaires (Appendix A). For example, it could be easier to identify difficulties in time-limited activities (item 1) when a group of children is involved, and the target child could be observed as being late compared with the others. Also, daily routines (items 3 and 4) are usually more regular in the school context compared with the domestic one, so it could be easier

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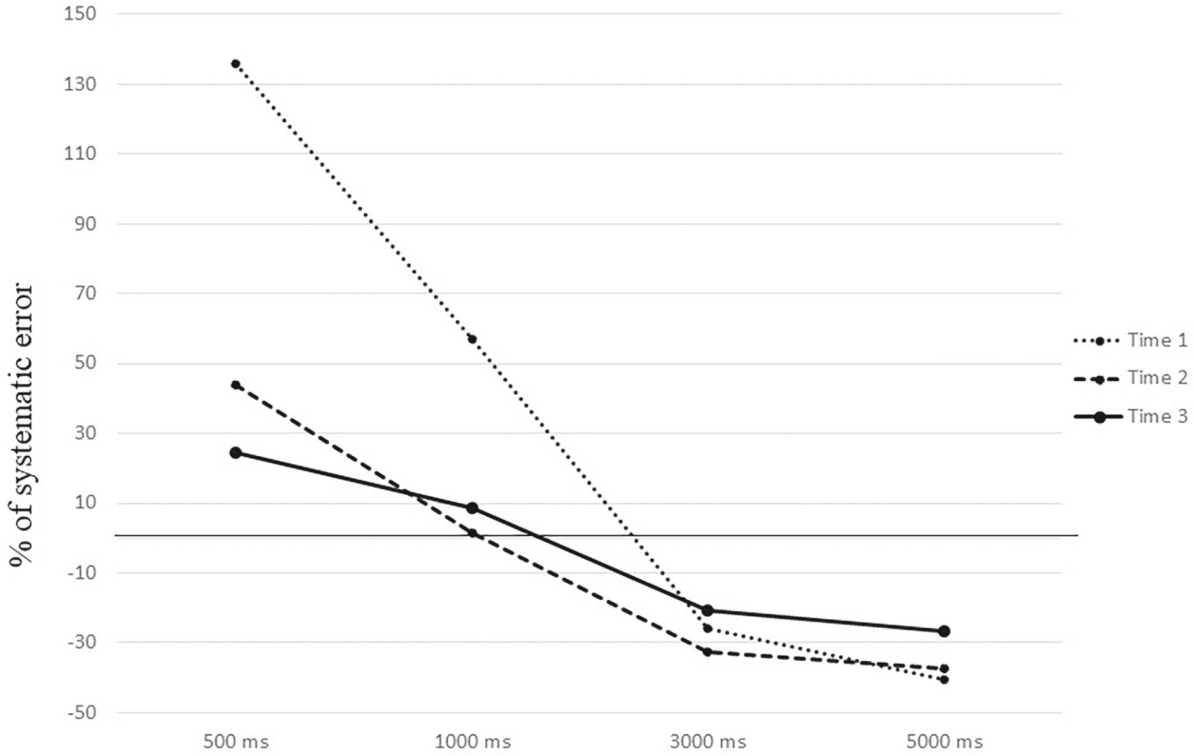

Figure 2. Time reproduction % of systematic error for durations of 500, 1000, 3000, and 5000 ms at Time 1, Time 2, and Time 3.

for a teacher to identify difficulties with them. In relation to this, Eiser and Morse (2001) give an overview of the aspects on which greater agreement is observed between different reports regarding observable variables (e.g., domains reflecting physical activity, functioning, and symptoms), while less agreement is registered for non-observable functioning (e.g., emotional or social quality-of-life-related variables). In this line of reasoning, discrepancies between teachers' and parents' reports could stem from the fact that children's sense of time can be only indirectly inferred by behavioural observations. Considering the longitudinal links between teachers' scores on the questionnaire and single time-processing tasks, it can be observed that both time discrimination and time reproduction were predicted, but for this last task, the link was significant only for short durations, contrary to a previous study showing a significant path for both short and long durations (Tobia et al., 2019). The mechanisms involved in the reproduction of short and long durations could be partially different, with the reproduction of longer durations needing more cognitive control and strategies (e.g., counting), and the reproduction of 500 ms duration being processed implicitly (Rammsayer, 1999). It could be that the time-related skills detected with the questionnaire in kindergarten are the ones associated with this more implicit process.

A further significant addition to previous studies was the inclusion of a task assessing the comparison of durations, which was significantly predicted by the teachers' questionnaires. This task is based on habits that children should know well (drawing, dressing), and we know that children from the age of 3 learn routines and can report what they do in the correct temporal order (Forman, 2015). Therefore, this skill should be well developed in 1st grade and, based on the present results, should be based on children's sense of time as detectable by teachers in kindergarten.

Early development of time-processing skills and sense of time

As for the development of time-processing from the beginning to the end of the last year of kindergarten, until the end of 1st grade, results were partially different based on the task and time intervals considered. The analysis of the time reproduction task showed a significant improvement from T1 to T2 for the shortest durations (500 and 1000 ms), without further improvement at T3. For the longest duration (5000 ms) the improvement was observed at T3 whereas the two performances measured at kindergarten were similar. Finally, for the duration of 3 seconds, a non-linear pattern of change was observed. As for time discrimination, results showed a linear improvement in children's skills, with accuracy

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increasing from kindergarten to 1st grade and RTs linearly increasing from T1 to T2 and then to T3. A possible explanation for these results can be based on Levin and Wilkening's (1989) observations: during the first year of primary school, children learn algebraic addition rules and this competence makes them more skilled in the time reproduction task. Also, Droit-Volet (2016) showed that preschoolers do not process the stimuli in time-processing tasks the same way as older children because these tests are strongly correlated with working memory, which increases with development, explaining the improvement in time-processing competence during the years of primary school. Finally, as highlighted by Hamamouche and Cordes (2020, 2023), in primary school children acquire more knowledge of temporal symbols, which are related to time-processing skills, plausibly supporting their improvement. The acquisition of temporal symbols and the improvements in the ability to measure time could also be the reasons for the higher scores observed in the Sense of time questionnaire at T3, compared with T1, both considering the parent and teacher versions of the questionnaire. As for this last version, it is worth noting that the teachers rating the child at T1 and T3 were not the same; again, a significant improvement was observed.

Limitations and future directions

A limit of the present study could be related to the time-processing tasks used for the present study: adding a bisection task should be important, also for comparing results with past studies (Droit-Volet et al., 2003). Another important limit is the lack of information on children's memory, verbal, and attention skills, considering the important role of these cognitive abilities in influencing performances in time-processing tasks (Droit-Volet, 2016); in line with this, a measure of counting and calculation skills would be important for assessing the role of these numeracy abilities in influencing time-processing development (Droit-Volet, 2016). Then, a test of the ability of the Sense of time questionnaire scores in identifying children with an actual deficit in time-processing has not been provided in the present study and should be done in future longitudinal studies, run with larger samples for obtaining greater statistical power. In addition, familiarity with the tasks could alter the final results; this possible alteration should be checked with control groups. Finally, some context-related factors, such as the teachers' years of experience and the size of the class groups, could have had an impact on the teachers' ability to rate their pupils' sense of time, and should be considered in future studies.

Among the future perspectives, it could be interesting to add further testing points to assess the developmental trajectory of time-processing skills in the following years of primary school; also, with a larger sample, it would be possible to investigate any differences in these trajectories between children with adequate or poor time-related skills.

CONCLUSION

The analysis of the literature has made it possible to highlight the importance of time-processing skills as possible early indicators related to neurodevelopmental disorders (e.g., ADHD).

The main aim of this study was to assess if a questionnaire measuring the sense of time (Tobia et al., 2018), filled in by teachers and parents in the last year of kindergarten, is a good predictor of children's time-processing skills. The results showed that the teacher version of the questionnaire was able to predict different time-related skills (i.e., time reproduction and discrimination, comparison of events' durations, sense of time) from the beginning of the last year of kindergarten to 1st grade, proving its validity as a tool for investigating time-processing skills in young children. Also, they suggest that teachers are competent observers and could be involved in the early identification of alarm bells related to deficits associated with time-related deficits, such as dyscalculia (Moll et al., 2016) and ADHD (Ptacek et al., 2019).

ETHICS STATEMENT

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee at the University of Milan-Bicocca and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

INFORMED CONSENT

Informed consent was obtained from all parents of the children included in the study; assent was obtained from children.

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APPENDIX A

Sense of time scale

1 My child/pupil is able to end a time-limited activity before the time is up
2 My child/pupil talks about past events in a correct way (speaking about them as they were already past and not as present or future events)
3 My child/pupil seems to know what to expect during daily routines (e.g., get ready for school/home; snack time)

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4 My child/pupil autonomously realises when a daily routine is approaching (e.g., lunch time; getting ready for outdoor activities)
5 My child/pupil asks 'what time is it?' or refers spontaneously to times and durations during the day
6 My child/pupil understands terms such as 'yesterday' and 'tomorrow'
7 My child/pupil correctly uses terms such as 'yesterday' and 'tomorrow'
8 My child/pupil understands terms such as 'before' and 'after'
9 My child/pupil correctly uses terms such as 'before' and 'after'

Filler items

My child/pupil likes to spend time at the park/ in the garden
My child/pupil prefers sweet foods
My child/pupil likes to play to games that imply physical movement, such as running and jumping
My child shows interest in cartoons/My pupil likes to listen to stories told or read by the teacher

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