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Jean Ecalte, Emilie Dujardin, Christophe Gomes, Laurent Cros, Annie Magnan

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Jean Ecalles<sup>a\*</sup>, Emilie Dujardin<sup>a,b,c</sup>, Christophe Gomes<sup>c</sup>, Laurent Cros<sup>c</sup>, and  
Annie Magnan<sup>a</sup>

<sup>a</sup> *Lab EMC - Etude des Mécanismes Cognitifs, Université Lyon2, MSH LSE (USR CNRS 2005) – Université Lyon - France*

<sup>b</sup> *Lab CeRCA, Centre de Recherches sur la Cognition et l'Apprentissage, Université Poitiers, France*

<sup>c</sup> *Association Agir pour l'Ecole, Paris, France*

[ecalle.jean@wanadoo.fr](mailto:ecalle.jean@wanadoo.fr); [jean.ecalle@univ-lyon2.fr](mailto:jean.ecalle@univ-lyon2.fr)

[emilie.dujardin@univ-poitiers.fr](mailto:emilie.dujardin@univ-poitiers.fr)

[christophe.gomes@gmail.com](mailto:christophe.gomes@gmail.com)

[laurent.cros@gmail.com](mailto:laurent.cros@gmail.com)

[annie.magnan@univ-lyon2.fr](mailto:annie.magnan@univ-lyon2.fr)

## **Effects of a two-year literacy intervention from Kindergarten to Grade 1: A differential approach**

### *Abstract*

Two groups were formed in a randomized, controlled trial: an Experimental group (n = 346), which benefited from specific interventions by trained teachers for a period of two years, and a Control group (n = 1354) with business as usual. For Experimental group in Kindergarten, the interventions were conducted in small groups and focused on code-related and language skills (mainly in comprehension), whereas in Grade 1, only code-related skills were addressed and the children received an amount of exposure that was a function of their performance level. Globally, Experimental group significantly outperformed Control group in code-related scores (Code) as well as on two reading scores (fluency and comprehension) at the end of Grade 1. Results were subdivided into quintiles for analysis as a function of initial performance. The main results shown that in Code Experimental group in the lowest quintiles obtained better performance at the end of Grade 1.

Keywords: literacy; instruction; response to intervention;

### **Introduction**

This article only covers the pencil-and-paper interventions (without computer-based instruction) was conducted in the classroom by teachers before and at the beginning of

primary school. After publishing the effects of such interventions for each year separately, first in Kindergarten and then in Grade 1 (see below), we will now analyze the differential effects of interventions on literacy skills in this two-year longitudinal study carried out with French children.

### ***Literacy interventions in the first years of learning to read***

When children enter Kindergarten and Grade 1, early classes dedicated to learning to read in most countries, it is important to be aware of the best predictors of reading achievement in order to provide children with the specific stimulation they need during these two important school years. The literature has traditionally shown that Kindergarten children's early literacy and oral language skills predict reading achievement. Early literacy skills, and primarily letter knowledge (letter name and letter sound), phonological awareness and grapheme-phoneme correspondences, are the strongest early literacy predictors of later reading decoding, while oral language skills, including vocabulary and language comprehension, are associated with reading comprehension (see the recent meta-analyses: Hjetland et al., 2020; January & Klingbeil, 2020). Kindergarten end-of-year reading performances predict reading trajectories from first to fourth grade (Spira et al., 2005). According to the Simple View of Reading, in which comprehension is the product of decoding and language skills, Kindergarten children at risk for reading difficulties may have difficulties in code-related competencies (phonological awareness, print knowledge, grapheme-phoneme correspondences, decoding), meaning-related skills (oral language), or both skills (Catts et al., 2006; Schatschneider et al., 2004). However, Al Otaiba et al. (2023) observed that "the magnitude of effect sizes on standardized reading measures was greater on code-focused measures (ranging from 0.41 to 0.62) than on meaning-focused measures (ranging from 0.32 to 0.36)".

Numerous studies indicate that interventions in these two domains can improve language and early literacy skills (NELP, 2009; Diamond et al., 2013). The National Early Literacy

Panel (NELP) examined the effectiveness of Preschool and Kindergarten programs developed to improve early literacy skills (Lonigan & Shanahan, 2008), particularly for children at risk for later reading difficulties (Lonigan & Cunningham, 2013; Lonigan et al., 2008). Code-focused programs involve teaching the alphabetic principle (letters in written language correspond to sounds in spoken language) and explicitly teaching phonological awareness skills. These programs improve children's phonological awareness and print knowledge abilities as well as their later reading and writing skills. Currently, there is ample evidence that reading difficulties can be reduced and even prevented through intensive early evidence-based interventions (Gillon et al., 2022; Lovett et al., 2017; Vellutino & Zhang, 2008). Many researchers argue that an intervention in Kindergarten and/or in Grades 1 and 2 is more effective than later intervention, partly because interventions must be intense and long-lasting if they are to be effective and partly because of the difficulty in improving fluency rates (Ehrhardt et al., 2013; Foorman et al., 2003; Torgesen, 2002).

Many of these studies have been conducted with English-speaking children. In France, two large-scale studies have been conducted using pencil-and-paper interventions. The first, conducted by Bianco et al. (2010; 2012), led to the publication of two papers reporting on children observed over three years from Preschool<sup>1</sup> to Grade 1, some of whom were trained for one semester (Kindergarten) and some for two semesters (Preschool and Kindergarten). In their first paper, the authors showed that interventions targeting oral comprehension skills have a lasting effect in Grade 1 in two conditions: in comparison with control groups, children who had been trained for two semesters by means of well-defined comprehension-focused activities were those who obtained better performances in oral comprehension in Grade 1. The results were similar for phonological awareness training. In their second paper, the authors

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<sup>1</sup> In France, children aged 3 to 5 are enrolled at the Ecole Maternelle, from Petite Section, then Moyenne Section (so-called Preschool) and on to Grande Section (Kindergarten); then, aged 6, they enter Grade 1 in Primary School.

showed that phonological awareness training in Preschool and Kindergarten has a positive effect on reading skills (words and pseudowords) in Grade 1, while comprehension training has a positive effect on reading comprehension in Grade 1. The following large-scale study presented here was conducted over a period of two years with children from disadvantaged areas. In a randomized, controlled trial with Kindergarten children, Ecalle et al. (2015) reported evidence of the efficacy of interventions on language and literacy. Evidence-based literacy practices were administered by teachers to an Experimental group, while a Control group received no specific intervention during the same period. The training focused on the alphabetic code, phonological awareness and listening comprehension. The results showed that the children in the Experimental group made significant gains in the targeted domains as well as in pseudo-word reading. The gains were higher in children who had the lowest pre-test scores. In a second paper, Ecalle et al. (2019) examined the effects of code-focused interventions in Grade 1 on the reading skills at the end of Grade 1 of low-performing children (assessed before intervention). Results showed that word reading, word spelling, and fluency were significantly improved in comparison to the control group. Moreover, reading comprehension performances were unexpectedly better in the trained group, even though no comprehension skills had been trained.

To summarize, research has shown greater gains in oral language and early literacy in children who have followed a program in which knowledgeable teachers have provided explicit oral language and early literacy instruction (Piasta et al., 2009). Moreover, children learn more when oral language and early literacy instruction is embedded in classroom activities (Horn et al., 2000). However, there is still the issue of heterogeneity in the ability to learn to read and how children respond to interventions.

### ***Heterogeneity in the first years of learning to read***

Although many instructional activities have been evaluated, few studies have examined the potential impacts of Response to Intervention (RTI) approaches in young children. RTI is a multi-level approach used by schools to permit the early identification of children with learning and behavioral needs. The RTI process starts with a screening of all the children in the general education setting. The data clarifies which students are in need of interventions in specific domains. Children identified as being "at risk" after this universal screening receive supplemental instruction (Berkeley et al., 2009; Shapiro, 2009). In the Response To Intervention framework, core classroom instruction (Tier 1) represents high-quality, general, evidence-based education. Tier 2 involves more intense instruction, often delivered to small groups and usually by the teacher in the classroom (this is exactly the procedure followed in the Ecalle et al.' study (2019)). Tier 3 involves an even higher level of intensity, often delivered as a supplement provided by a paraprofessional or specialist.

Some researchers have tested models that begin Tier 2 in Kindergarten (e.g., O'Connor et al., 2005; Simmons et al., 2008; Vellutino et al., 2006). Scanlon et al. (2008) compared Kindergarten children who received Response To Intervention instruction from teachers who had not undergone specific training with children taught by teachers who had taken part in a program designed to increase their knowledge and skills in understanding children's needs and help them identify the appropriate technique, materials and strategy for supporting struggling readers. The reading skills of children who benefited from reading programs administered by professionally trained teachers improved significantly, and the number of children identified as "at risk" was cut in half (35% to 17%). For children in Kindergarten through Grade 3, higher effects have been found in studies with one-to-one instruction or very small groups than with larger groups (Wanzek & Vaughn, 2007). A recent meta-analysis (Denton et al., 2022) examined the effects of individual or small-group reading interventions on the reading comprehension of elementary school children with reading disabilities. The

results confirm that small-group or one-on-one interventions that include a basic reading skills component are likely to have a positive impact on reading comprehension ability when provided to struggling Kindergarten to Grade 3 children. An overall weighted mean effect size of .37 on normative reading comprehension performance indicates that small-group or individually administered reading interventions have a significant effect on the reading comprehension of students with reading difficulties. Suggate (2010) and Wanzek et al. (2016) reported similar effects.

However, we are not aware of any longitudinal studies that have addressed the issue of the differential effects of training in the context of such interventions: Are all children with learning difficulties responsive to interventions and to what extent? We will examine this question.

### **Research Questions**

Before analyzing the evolution of literacy performances, we must first identify the constructs that subsume all the tasks used in various domains during these two years dedicated to learning to read. Classically, we can expect to identify two dimensions, one covering code-related skills and the second oral language skills. Two questions will thus be addressed in the light of this:

1/ Globally, how do performances on the two dimensions, code-related and oral language skills evolve during the two years in the two groups, one with literacy interventions and one without?

2/ As a function of initial performances, to what extent do such literacy interventions over two consecutive years impact performance on the two dimensions and also on reading at the end of Grade 1?



## Method

### *Participants*

In a two-year longitudinal study, 1700 children (865 girls; 835 boys) were followed from the beginning of Kindergarten to the end of Grade 1. They were randomly assigned to one of two groups, one receiving literacy interventions during the two years (see below),  $n = 346$  (Experimental group; Exp: mean age at start = 64.4 months;  $sd = 3.5$  m.) and a Control group,  $n = 1354$  (Cont; m. a. = 64.8 m.;  $sd = 3.6$  m.) receiving no specific interventions, that is going about their normal school activities as usual. No atypically developing children were included in this study and all were French-speaking.

Only schools in REP (*Réseau d'Education Prioritaire*: zones with specific educational needs) and distributed across two regions (North and South) of France participated in this study, which was approved by the academic authorities, and which involved teachers who volunteered to take part in the study. 21 schools were enrolled for the Experimental group and 58 for the Control group. The average class size was very similar in the two groups, at around 20 children. The socio-economic status (SES) of the two groups in terms of the number of children from low SES (Cont: 55%; Exp: 54%), and middle and high SES backgrounds (respectively, 24% and 13%) was also balanced.

### *Measures*

A set of measures assessing two domains related to literacy, code-related and language skills was administered to the children in four sessions: one at the beginning of Kindergarten (t1), one at the end of Kindergarten (t2), one at the beginning of Grade 1 (t3) and the last one at the end of Grade 1 (t4). There were no missing data. To avoid saturated scores (ceiling effects), we had to change and/or adapt the tasks as a function of the assessment session. The tasks in Kindergarten are presented in detail in Ecalle et al. (2015) and those in Grade 1 in Ecalle et al. (2019). Table 1 summarizes the tasks proposed during the two years and presents the characteristics of the different measures. All the tasks except the last two were

administered collectively by the class teacher in small groups (4 to 6 children maximum). The same task was sometimes administered in different sessions (word reading, vocabulary, listening comprehension) but with more or less items. For example, the number of items in the letter knowledge task (LNK) was reduced at t2 because the task proved too easy, whereas the number of items in the word reading task was increased (at t4). In the case of vocabulary, because high scores were observed at t1, only those items with the lowest scores were retained at t2. For reading comprehension at t4 (RC4), a global score was calculated using the total of the scores in the two reading comprehension tasks. For fluency, the score was calculated using the following formula:  $(50 - \text{Errors}) / (\text{Time in seconds} * 60)$ .

### *Literacy interventions*

Literacy interventions were proposed during the second and third semesters of the school year (from January to June) in Kindergarten (Ecalte et al., 2015) and Grade 1 (Ecalte et al., 2019). In Kindergarten, two aspects of literacy skills were targeted, namely code-focused processes and meaning-focused processes (also called language skills; primarily comprehension in this case; see below). The first concerned phonological awareness and alphabetic code training: for example, children were asked to listen to oral words and then to perform segmental analysis, first at the syllable level and then at the phoneme level; for alphabetic code, the training sessions focused on letter knowledge, and more specifically letter-name and letter-sound knowledge. For language skills, only listening comprehension skills were trained. This training involved four modules (so-called "situation model", "detection of inconsistencies", "causality" and "anaphora") which were designed to help promote a better comprehension of narrative. To help them during these sessions (code-focused and comprehension), the teachers had two handbooks (one dedicated to each domain) to help them organize the sessions. However, before using these handbooks by themselves in their classrooms, they were instructed by educational advisors to teach the children in small homogeneous groups of

children with the same level in literacy skills (4-7 per group), while the other children continued to perform their normal classroom activities. Code-focused skills were trained twice a week and comprehension once a week. Globally, each child received approximately 9 h of oral comprehension training and 18h of alphabetic code and 18h of phonological training. In Grade 1, only code-focused skills were trained after the teachers had been instructed (in a one-day course) about how to use the handbook dedicated to code learning. This training was administered in four successive domains: phonological skills, letter sound, decoding and fluency. The teachers were asked to propose exercises adapted to the children's initial level. For example, once the children reached a high level of performance in phonological skills, letter sound correspondences were trained; when they had mastered letter-sound knowledge, they were trained in decoding and then, finally, in fluency. For this fourth domain, children were encouraged to read short texts as quickly and accurately as possible during the course of repeated reading activities. Teachers were recommended to allocate 30 min a day to working in small groups and 2\*30 min a day for the lowest performing children. However, the amount of training depended on the children's initial level: the lower this level was, the more training they received (see Ecalle et al., 2022). Teachers were supported by educational aids only during group teaching. Before the training, the children's literacy skills were assessed and the children were assigned to a group depending on their initial level.

To summarize, code-related skills were trained for the whole two-year period, whereas comprehension was trained only in Kindergarten, meaning that much more training time was devoted to code. During the two years, compliance with the protocol was monitored by experimenters from an association<sup>2</sup> who performed weekly follow-up.

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<sup>2</sup> This protocol was constructed by one of the co-authors.

### ***Analyses***

A series of analyses were conducted. The aim of the first was to obtain two weighted scores on the same scale in the four sessions. This scale related to the two dimensions classically involved in reading, that is one to code-related skills and the second to oral language skills. After first examining the global effect of interventions, we conducted a second set of analyses as part of a differential approach. More specifically, we examined how performance evolved as a function of initial performance on the two dimensions in the two groups (Experimental vs Control).

## ***Results***

### *Descriptive data on raw scores*

Even though we tried to adjust the difficulty of the tasks to be appropriate for the different evaluation sessions, it can be seen that some overall ratings are very high, with success rates close to or above 80% (see Table 1: Voc1, Voc2, LSK3, Voc3, WR4, Voc4 and LC4).

The large number of tasks (and scores) and the great variations between sessions on the same tasks led us to determine two "general" scores from each domain (code-focused skills and language skills) and then to calculate weighted scores on the same scale.

### *Calculating weighted scores*

To do this, we first conducted a confirmatory factor analysis for each session, with the scores being associated with one of the latent variables (the construct), i.e., code-related skills (referred to as Code) or language skills (Lang) (see Table 1). To improve the model fit, the modification indices module was used if necessary (with Stata 16). The models are presented in Figure 1 and their goodness of fit in Table 2. We can observe that the coefficients vary between sessions; for example, the contribution of phonological skills to Code improves between t1 and t2 (.73 and then .80) and that of word reading also improves from t2 to t4 (successively, .41, .55, .82).

We then used the coefficient between each manifest variable score and the construct, to calculate a weighted Code and Lang score, meaning that each task contributed to this score for each session at the level indicated by the coefficient in the model. For example, for Code1 (session at t1), we computed the weighted score using the following formula on the basis of the raw scores in each task:  $\text{Code1} = (\text{LNK1} \cdot .59) + (\text{PhSk1} \cdot .76) / \text{max}_w$ , where  $\text{max}_w$  is the weighted maximum calculated based on the maximum value for each task contributing to Code1, letter-name knowledge and phonological skills:  $\text{max}_w = (26 \cdot .59) + (18 \cdot .76)$ . For fluency (Flu4) and reading comprehension (RC4), we calculated the same weighted score on the basis of the maximum. All the weighted scores therefore share the same scale (0 to 1).

*Descriptive data and correlation matrix for weighted scores*

Table 3 presents descriptive data for the two groups for the Code and Lang constructs and the two variables Flu4 and RC4. In Table 4, all correlations are significant.

*Examining the global effect of interventions on weighted scores in literacy*

A Manova was conducted with Session as a within-factor and Group as between-factor. For Code, a significant effect of Session was found,  $F(3,5094) = 1013.94, p < .0001$ , with scores increasing from t1 to t2, decreasing from t2 to t3 and then increasing again from t3 to t4 (.555, .642, .600, .831). The Session\*Group interaction was also significant,  $F(3,5094) = 21.61, p < .0001$ , with the differences between the groups changing from t1 to t4 (see Table 3): in favor of Control group at t1 (.575 vs .536), with no significant differences between groups at t2, and then in favor of Experimental group at t3 (.616 vs .584) and at t4 (.851 vs .811). For Lang, the results of the Manova showed only a significant effect of Session,  $F(3, 5094) = 285.27, p < .0001$ , with the scores changing from t1 to t4 in the same way as for Code (.747, .812, .771, .866). Finally, for fluency and reading comprehension at t4, the Student t test revealed significant differences between groups in favor of Experimental group (see Table 3), with moderate effect sizes (between .30 to .35).

*Examining differential effects as a function of initial weighted scores*

We examined the evolution of performances in the 5 quintiles (Q) successively based on the scores at t1 for both Code and Lang, from Q1 with the lowest scores to Q5 with the highest scores (Table 5). A Manova was then run on the weighted scores for each quintile, with a between-factor Group (Experimental vs Control) and a within-factor Time (t1, t2, t3, t4). Because we expected the Experimental group to progress more than the Control group, we will examine only the Group\*Time interactions for the Code and Lang constructs and observe whether the differences between the two groups were significant for each session.

For Code, the interactions in the 5 quintiles were significant ( $p < .001$ ). Figure 2 shows the evolution of the Code scores from t1 to t4 and Table 6 indicates the differences (and their

effect sizes) between the two groups: t2 after the first intervention in Kindergarten, t3 before the beginning of the second intervention in Grade 1, and t4 after this intervention in Grade 1. First of all, we observe that in all quintiles, there was no significant difference between performances at t1. The short-term effects of intervention in Kindergarten (at t2) are significant in Q2, Q4 and Q5. The mid-term effects of the first intervention (at t3) are still significant in Q2 to Q5. Finally, the effects of interventions at t4 are significant in all quintiles, and more importantly in Q1, Q2, Q3 with high effect sizes, whereas the effect sizes are more moderate in Q4 and Q5. Moreover, the impacts of fluency and reading comprehension interventions at t4 in are also significant in favor of Experimental group (see Table 6).

For Lang (Figures 3), the Group\*Time interaction is significant for Quintile 1 only ( $p < .05$ ). Unexpectedly the differences at t1 are in favor of Control group, which achieved significantly higher scores; and we found only one significant difference in favor of Exp group at t4. Finally, the differences between the two groups' fluency and reading comprehension scores are significantly in favor of Experimental group for quintiles 2 to 5 (Table 6).

## **Discussion**

### ***Effects of this two-year intervention***

This present study complements two earlier studies for which data were analyzed separately in Kindergarten and then in Grade 1. The aim here was to examine the effects of interventions over a period of two years in an Experimental group compared to a Control group which continued its normal classroom activities as usual. It is important to remember that the interventions in Kindergarten focused on two dimensions, namely code and comprehension (with more hours of instruction being dedicated to code than comprehension), whereas only code was addressed in Grade 1. Another difference between the interventions in

Kindergarten and Grade 1 was the time allocated to children: in Kindergarten all the children in the groups benefited from the same intervention durations, whereas the teachers in Grade 1 allocated time in the light of the reading difficulties experienced by the children. This second approach clearly relates to Tier 2 in the Response To Intervention framework.

First of all, we are able to distinguish between the two dimensions that underpinned all the tasks. These preliminary analyses allowed us to obtain weighted scores that accurately reflect the children's level throughout the two years on both dimensions, i.e., code and language. This enables us to observe the evolution of performance on the same scale in the two dimensions, i.e., Code and Lang. Globally, we observe a significant effect of interventions on weighted scores at t3, but not at t2 at the end of Kindergarten. This mid-term effect observed after the summer holidays means that the interventions are effective for Exp group when children start learning to read. The effects on Code observed at t4 in favor of Experimental group are more consistent. However, these effects are not observed in language skills (Lang). This is not surprising given that less training was devoted to comprehension skills (only in Kindergarten) and no vocabulary training was provided. Another interesting result is revealed by the two reading scores at t4, namely the fluency and reading comprehension scores, with Experimental group achieving higher scores than Control group.

Using the differential approach enabled us to observe how Code and Lang evolved as a function of the initial performance levels by considering the performance quintiles at t1. Even if no evidence of the impact of the interventions was identified for Lang (except for Q4 at t4), these effects were clearly observed for Code in all five quintiles. As expected the children with the lowest scores (the first three quintiles, Q1, Q2, Q3) made the most progress on Code and exhibited the largest effect sizes. Another result should be highlighted: with the exception of Q1, the advantage of Exp group at the end of Kindergarten is still present at the beginning of Grade 1 (at t3). This advantage of the Experimental group is still evident at t4 for both



fluency and reading comprehension: in fact Experimental group significantly outperformed Control group in all five quintiles.

All of these results are consistent with the types of interventions proposed. Indeed, we have emphasized that, except in Kindergarten, fewer hours were dedicated to comprehension skills, with most of the time spent during the two years being dedicated to the different levels of code instruction, i.e., phonological skills, letter knowledge, decoding, and fluency in Grade 1. There was therefore no training in comprehension skills during the second year and no vocabulary training at all during the two-year period. More specifically, in Grade 1, the children who achieved a good level of decoding were also trained in fluency. This approach (starting with decoding training, followed by fluency training) has been supported and justified in other papers (see for example, Ecalle et al., 2021; Juul et al., 2014; Karageorgos et al., 2019). In fact, fluency can be trained more effectively from a decoding accuracy of approximately 75%. Fluency training in this study consisted in repeating short texts. This exercise develops automaticity of word reading, leading to a lower cognitive load due to word reading and freeing up more cognitive resources for comprehension. This phenomenon explains why Experimental group also outperformed Control group in reading comprehension at t4.

### ***Limitations***

The assessment of vocabulary was problematic at two levels: firstly, we were unable to find a suitable task for the four sessions and secondly, we needed to investigate both breadth and depth of vocabulary. Comprehension skills might also have been strengthened during the Grade 1 intervention. However, as mentioned above, when code, and more specifically fluency, is trained, we can expect an indirect impact on comprehension and this is indeed what we observed. Finally, it would have been necessary to perform a follow-up over at least one more year in order to determine whether there is a potential long-term effect (see below).

### ***Factors impacting the interventions***

Several factors contribute to the effects of the intervention. Three of the most important are discussed below: the person who delivers the intervention, the conditions (group and trained skills), and the duration (dosage).

The effective implementation of interventions depends not only on the content but also on the person responsible for delivering them (Marulis & Neuman, 2010). In a review of the literature on effective reading interventions, Slavin et al. (2011) found that interventions delivered by certified teachers were more effective than those delivered by paraprofessionals and volunteers. However, irrespective of who it is who actually delivers the intervention, its effectiveness depends on the training received by the instructor. Studies have reported greater effects for interventions administered by researchers (Dignath & Buttner, 2008; Ehri et al., 2001b). Different types of instructor have been involved in the various studies, namely teaching assistants (Ryder et al., 2008) or education assistants (Fried et al., 2012) or paraeducators (Vadasy & Sanders, 2010), specially trained instructors (Center et al., 1995), or regular teachers (Elbaum et al., 2000). One well-documented phenomenon is that interventions administered by adults trained to conduct them tend to result in larger effect sizes.

Research has consistently demonstrated the positive effects of small-group reading interventions on young children at risk for reading problems (Kamps et al., 2008; Nielsen & Friesen, 2012; Hall & Burns, 2018; Wheldall et al., 2017). Children's age affects small-group reading intervention outcomes and the differences are greatest for preschool and kindergarten students (Suggate, 2016). The effects of small-group reading interventions administered to kindergarten children persist through to third grade (Simmons et al., 2008). In brief, the use of targeted, intensive interventions by trained teachers and group size are the two variables that are most strongly related to outcomes for children who are at risk for reading failure. The targeted approach to implementing a small-group intervention was defined by Burns et al.

(2012; 2016) as an intervention that focuses directly on one domain of the National Reading Panel (NRP, 2000) in the light of the children's needs.

The children with the greatest difficulties need more teaching time. In one of our studies (Ecalte et al., 2022), we found that in Tier 2 interventions in Grade 1, the amount of specific instructional time for reading (SITR) was linked to children's scores in reading-related skills and that SITR was linked to progress in fluency and reading comprehension. More precisely, the analyses revealed that 10 h of SITR should bring about a 20% improvement in fluency and 30% in reading comprehension. These results show that the teaching times devoted to beginning readers should be varied as a function of their performance level (Connor et al., 2016).

The third factor which is important in determining the effectiveness of an intervention is the intensity, or so-called intervention dosage. This is usually calculated by multiplying the number of teaching episodes per session by the number of sessions per week and then multiplying this by the length of the intervention in weeks (Warren et al., 2007). This concept involves factors such as the overall duration of the intervention, its frequency (number of sessions) and intensity (the duration of each session). Recent research that has directly studied the effects of intervention dosage has reported positive impacts of increased dosage (Hall et al., 2022; Al Otaiba et al., 2023). However, linear models of intervention research (Denton et al., 2011; Wanzek & Vaughn, 2007) and meta-analyses (Hall & Burns, 2018; Wanzek et al., 2016) do not provide clear support for the hypothesis that more hours of intervention (higher dosage) produce significantly greater effects than interventions with less hours of intervention (lower dosage). However, Roberts et al. (2022) very recently proposed a nonlinear meta-analysis as a method for identifying both the maximum effect size and the optimal dosage of reading interventions for children with reading difficulties from kindergarten to third grade. They observed a concave parabolic function indicating that increasing dosage improved

intervention effects up to around 40 hours of instruction, with the effects then declining after this threshold. Moreover, when children received one-to-one instruction, the effect of the intervention increased indefinitely after approximately 17 hours. Thus, for children from Kindergarten to Grade 3 who, after 40 hours of instruction, still have significant reading difficulties, one-to-one instruction is likely to be to a good intensification strategy.

Last but not least, a question remains concerning the long-term effect of this type of early intervention. Many studies have shown that reading interventions are effective in improving children's reading skills in the short term (for example, Bus & van Ijzendoorn, 1999; Ehri et al., 2001a; Suggate, 2010). It now seems to be important for researchers and practitioners to go beyond the study of short-term effects and try to determine whether reading interventions lead to longer-term gains (Blachman et al., 2014). Thus, while the evidence indicates that reading interventions generally benefit all readers, more extensive follow-up periods are needed to investigate the longer-term effects and determine if and how different profiles of readers respond to reading interventions (see Suggate, 2016 for a review). Future research developed in a differential perspective that examines individual differences in response to interventions (Al Otaiba et al., 2023) should provide answers to the question of which children benefit from reading interventions and under what conditions.

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Table 1

*Description of the tasks used in the 4 assessment sessions and their descriptive data.*

Session	Task	Name	Acronym	Domain (t)	max.	mean (sd)	skewn.	kurt.	$\alpha$
t1	Find the named letter among 7 letters	Letter Name Knowledge	LNK1	Code1	26	16.3 (6.01)	-.69	2.86	.93
t1	Oddity task: find the word among 3 which doesn't share the same unit (syllable or phoneme) Syllable deletion: after deleting the first syllable of a word, find the new word among 4	Phonological Skills	PhoSk1	Code1	18	8.94 (4)	-.05	2.3	.77
t1	Find the picture among 4 corresponding to the named word	Vocabulary	Voc1	Lang1	23	19.39 (3.75)	-2.53	12.2	.82
t1	After listening to a short text read by the teacher, answer the questions with possible responses presented together with the pictures	Listening Comprehension	LC1	Lang1	12	7.09 (2.95)	-.52	2.8	.72
t2	Find the named letter among 7 letters	Letter Name Knowledge	LNK2	Code2	15	11.89 (3.38)	-1.52	5.01	.86

t2	Oddity task: find the word among 3 which doesn't share the same unit (syllable or phoneme) Syllable deletion: after deleting the first syllable of a word, find the new word among 4	Phonological Skills	PhoS <sub>k</sub> 2	Code2	18	12.07 (4.12)	-.75	3.08	.80
t2	Find the written word among 5 corresponding to the oral word spoken by the teacher	Word Reading	WR2	Code2	10	2.53 (1.96)	1.13	4.35	.58
t2	Find the written pseudoword among 5 corresponding to the oral pseudoword spoken by the teacher	Pseudoword Reading	pWR2	Code2	10	5.32 (2.83)	-.06	1.97	.77
t2	Find the picture among 4 corresponding to the named word	Vocabulary	Voc2	Lang2	13	11.49 (2.02)	-2.61	12.95	.72
t2	After listening to a short text read by the teacher, answer the questions with possible responses presented together with the pictures	Listening Comprehension	LC2	Lang2	12	8.82 (2.68)	-1.03	3.96	.73
t3	Find the letter that is at the initial position in the named pseudoword	Letter Sound Knowledge	LSK3	Code3	15	12.68 (3.36)	-1.89	6.3	.92

t3	Draw as many circles as phonemes heard in a named pseudoword	Phonemic Segmentation	PhSg3	Code3	12	4.9 (3.12)	.54	2.52	.82
t3	Find the written word among 5 corresponding to the oral word spoken by the teacher	Word Reading	WR3	Code3	10	2.98 (2.09)	.89	3.58	.61
t3	Find the written pseudoword among 5 corresponding to the oral pseudoword spoken by the teacher	Pseudoword Reading	pWR3	Code3	10	6.21 (2.51)	-.36	2.27	.80
t3	Find the picture among 4 corresponding to the named word	Vocabulary	Voc3	Lang3	26	20.67 (3.52)	-1.97	9.07	.88
t3	After listening to a short text read by the teacher, answer the questions with possible responses presented together with the pictures	Listening Comprehension	LC3	Lang3	12	8.69 (2.23)	-1.21	4.52	.81
t4	Draw as many circles as phonemes heard in a named pseudoword	Phonemic Segmentation	PhSg4	Code4	12	8.12 (3.44)	-.67	2.32	.89
t4	Find the written word among 5 corresponding to the oral word spoken by the teacher	Word Reading	WR4	Code4	16	13.53 (3.3)	-2.02	7.07	.93

t4	Find the written pseudoword among 5 corresponding to the oral pseudoword spoken by the teacher	Pseudoword Reading	pWR4	Code4	10	8.6 (2)	-2.27	8.81	.88
t4	Find the picture among 4 corresponding to the named word	Vocabulary	Voc4	Lang4	8	6.98 (1.17)	-1.55	6.38	.90
t4	After listening to a short text read by the teacher, answer the questions with possible responses presented together with the pictures	Listening Comprehension	LC4	Lang4	8	6.89 (1.45)	-1.56	5.34	.81
t4	1/After reading short sentences above pictures to oneself, circle the picture corresponding to the sentence (/9) * 2/After reading aloud a short text (47 words) and reading questions about the text, answer the experimenter orally (/5)	Reading Comprehension	RC4	-	14	8.98 (3.7)	-.81	2.63	.86
t4	* After reading aloud a short text (50 w.), the experimenter records the time taken to read the text as well as the number of errors.	Fluency	Flu4	-	191	53.48 (34.38)	.70	3.41	-

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*Notes.* The two tasks with \* were administered individually by an experimenter.



Table 2  
*Goodness of fit of the models for the 4 sessions*

Models	$\chi^2(p)$	RMSEA	AIC	BIC	CFI	TLI	SRMR
Mt1 <sup>a</sup>	$\chi^2(1)=14.68$ (.000)	.09	-	-	.972	.835	.064
Mt2	$\chi^2(4)=49.66$ (.000)	.082	46941.29	47066.37	.982	.934	.024
Mt3	$\chi^2(8)=55.62$ (.000)	.059	47549.66	47652.99	.977	.958	.025
Mt4	$\chi^2(4)=22.24$ (.000)	.052	34979.92	35066.94	.989	.972	.025

*Notes.* RMSEA: root mean squared error of approximation; AIC: Akaike's information criterion; BIC: bayesian information criterion; CFI: comparative fit index; TLI: Tucker-Lewis index; SRMR: standardized root mean squared residual. <sup>a</sup>: the first model was calculated asymptotic distribution-free and the other three with maximum likelihood.

Table 3  
*Means (standard deviations) of weighted scores in the two groups (Control and Experimental) for the 4 sessions and comparisons between groups*

	Code1	Code2	Code3	Code4	Lang1	Lang2	Lang3	Lang4	Flu4	RC4
Cont <i>n</i> =1354	.575 (.189)	.633 (.188)	.584 (.179)	.811 (.183)	.747 (.163)	.809 (.159)	.775 (.128)	.866 (.139)	.276 (.177)	.653 (.25)
Exp <i>n</i> =346	.536 (.195)	.651 (.165)	.616 (.176)	.851 (.156)	.746 (.146)	.816 (.142)	.766 (.126)	.866 (.143)	.328 (.18)	.726 (.218)
post-hoc <i>p</i> Student	.0005 <sup>a</sup>	ns	.004	.0003	ns	ns	ns	ns		
<i>p</i> Cohen's <i>d</i>									4.86 <.0001	4.93 <.0001
	-.21	.10	.18	.23	-.01	.04	-.07	.00	.35	.30

*Note.* <sup>a</sup>: After the Manova, post-hoc tests (Newman-Keuls) were run.

Table 4  
Correlation matrix (N=1700)

	Code1	Lang1	Code2	Lang2	Code3	Lang3	Code4	Lang4	RC4
Lang1	.51								
Code2	.60	.41							
Lang2	.40	.54	.56						
Code3	.59	.34	.63	.35					
Lang3	.42	.48	.40	.51	.42				
Code4	.36	.24	.40	.25	.51	.31			
Lang4	.36	.47	.37	.52	.35	.56	.31		
RC4	.42	.37	.45	.39	.53	.45	.60	.46	
Flu4	.41	.24	.45	.26	.53	.26	.52	.26	.62

Note. RC4: reading comprehension; Flu4: fluency.

Table 5  
Ranges of weighted scores in the quintiles in Code and Lang

	Q1		Q2		Q3		Q4		Q5	
	Exp	Cont	Exp	Cont	Exp	Cont	Exp	Cont	Exp	Cont
Code	n=83	n=258	n=83	n=258	n=64	n=274	n=60	n=283	n=56	n=281
	.021 - .396		.397 - .522		.523 - .629		.63 - .738		.742 - .979	
Lang	n=61	n=274	n=77	n=261	n=68	n=263	n=77	n=261	n=63	n=295
	.054 - .62		.621 - .728		.733 - .808		.813 - .877		.882 - 1	

Table 6

*Differences between weighted scores for the two groups at t2, t3 and t4 (with Cohen's d) for Code and Lang in the 5 quintiles*

		t2		t3		t4		Flu4		RC4	
		diff	<i>d</i>	diff	<i>d</i>	diff	<i>d</i>	diff	<i>d</i>	diff	<i>d</i>
Code	Q1	.028	.17	.06	.04	.058	.27	.066	.45	.13	.51
	Q2	.049	.30	.08	.58	.063	.33	.062	.41	.094	.38
	Q3	.035	.23	.06	.43	.068	.47	.048	.31	.103	.46
	Q4	.048	.37	.05	.38	.032	.27	.049	.30	.07	.37
	Q5	.034	.27	.06	.44	.036	.27	.107	.56	.049	.29
Lang	Q1	.016	.13	.06	.38	-.049	.29	-.005	-.02	.02	.12
	Q2	.019	.13	-.02	-.14	-.016	-.11	.147	.62	.062	.38
	Q3	.014	.11	.00	.04	.019	.17	.051	.31	.11	.24
	Q4	.02	.19	.01	.16	.025	.27	.072	.40	.048	.24
	Q5	.014	.13	.00	.05	.014	.18	.049	.26	.048	.26

Note. Flu4: fluency at t4; RC4: reading comprehension at t4; diff: difference (Exp - Cont); *d*: Cohen's *d*; cells in gray: no significant difference at the post-hoc tests after Manova (see Figures 2) or after Student *t* (for Flu4 and RC4).

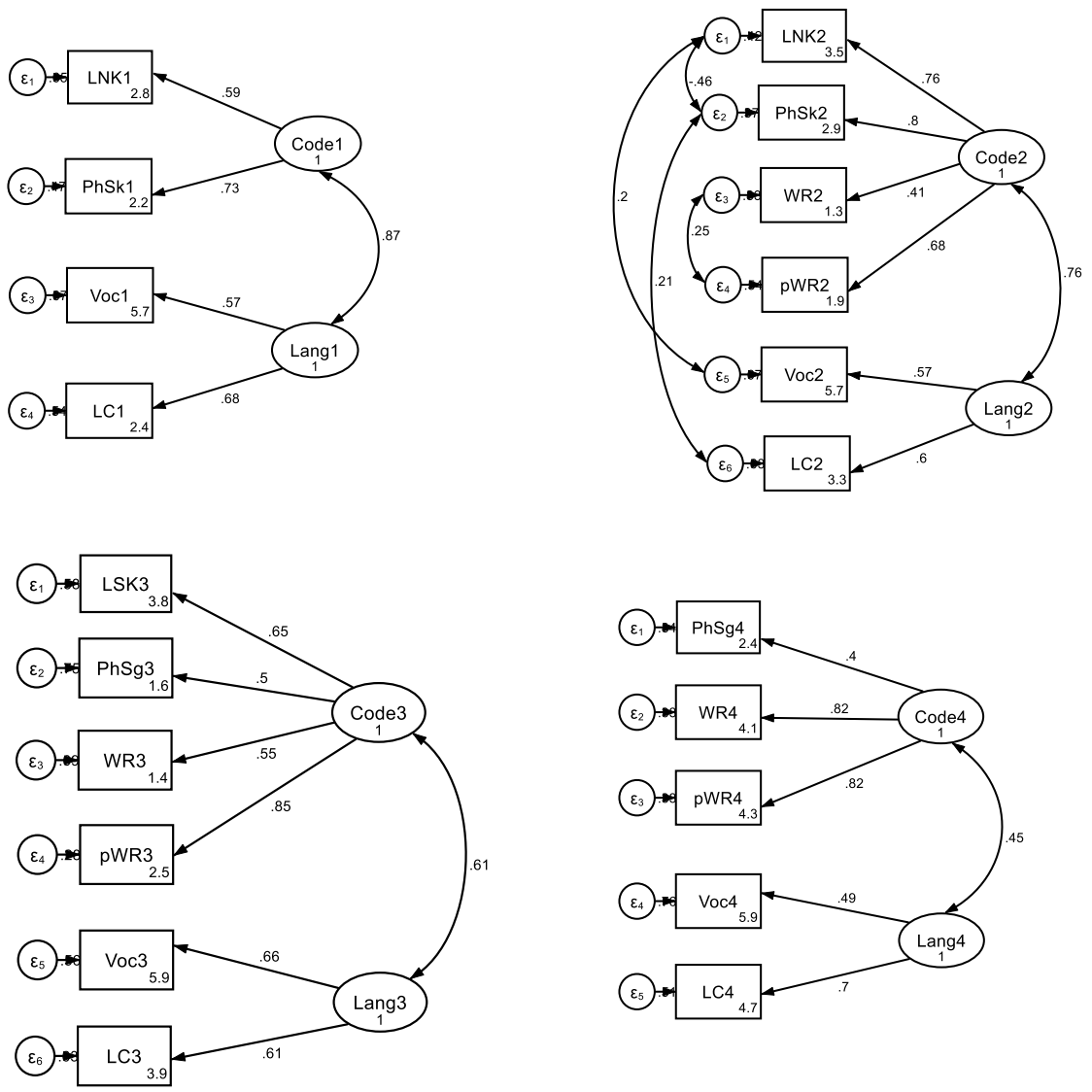


Figure 1  
 Models derived from CFA at t1 (upper left), t2 (upper right), t3 (lower left) and t4 (lower right)

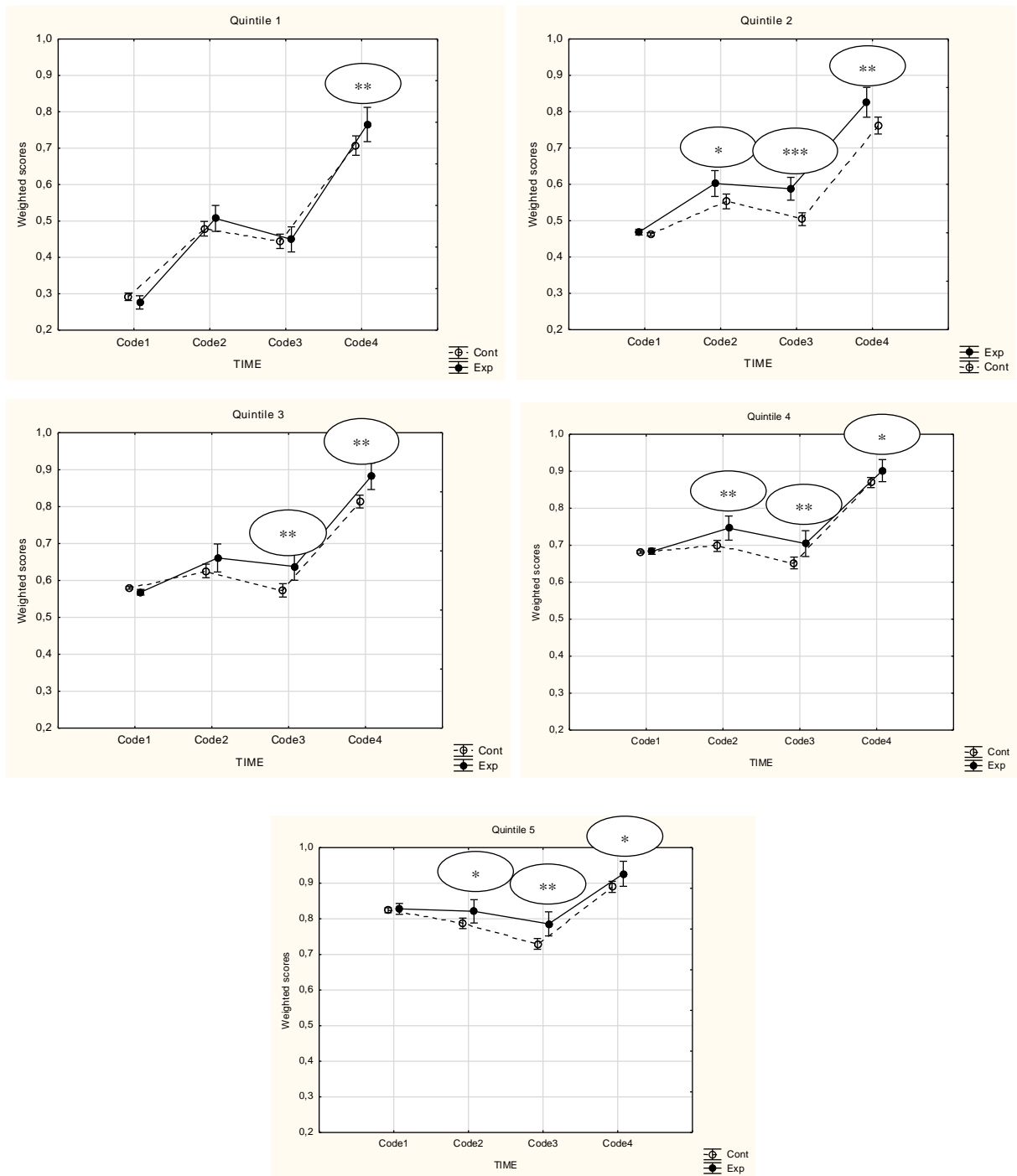
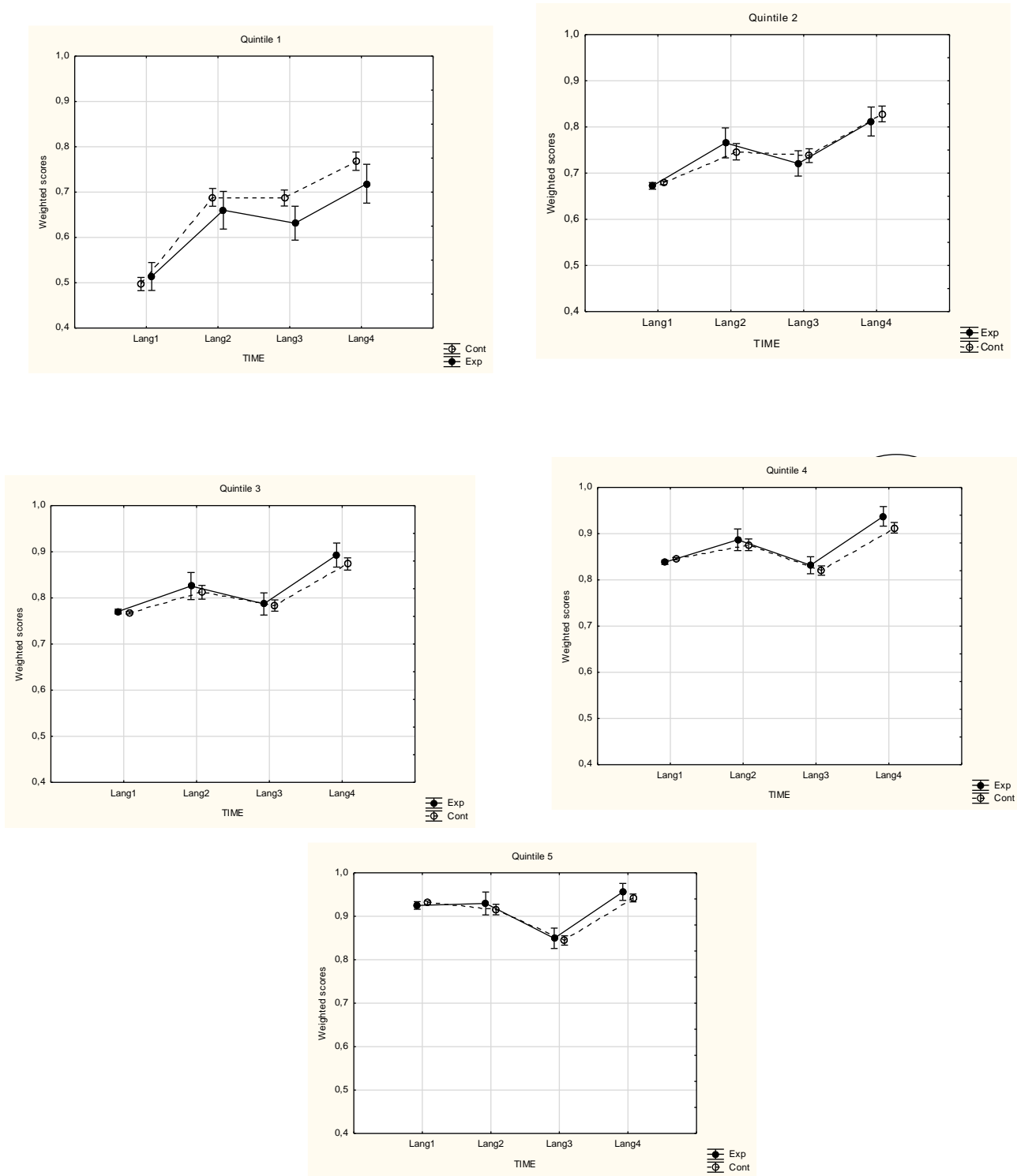


Figure 2

*Evolution of weighted scores for Code as a function of assessment time (t1 to t4) and group, i.e., experimental group (Exp) and control group (Cont).*

*Note.* The significant post-hoc tests (Newman-Keuls) between weighted scores for the groups are presented in the ellipses: \* ( $p < .05$ ), \*\* ( $p < .01$ ), \*\*\* ( $p < .0001$ ).



**Figure 3**

*Evolution of weighted scores in Lang as a function of assessment time (t1 to t4) and group, i.e., experimental group (Exp) and control group (Cont).*

*Note. The significant post-hoc tests (Newman-Keuls) between weighted scores for the groups are presented in the ellipses: \* (p<.05).*