What do I do next?

The influence of two self-cueing strategies on children's engagement of proactive control

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Abstract

Setting goals in advance of upcoming tasks is a critical aspect of proactive control. Using this mode of control is particularly challenging in young children, and increases in efficiency during school years. We tested the extent to which two self-cueing strategies can help kindergarteners, first- and fourth graders to set the goal in advance in a cued task-switching paradigm. Whether requesting verbal labeling of the task cue is necessary to induce proactive control was also investigated. Children were assigned to one of three conditions: they were required to be silent, or to identify the relevant task goal by labeling out loud the task name or by pointing at one of two pictorial representations of the task goals. Error rates showed that both strategies helped kindergarteners and first graders to engage in advance preparation. This finding suggests that prompting children to build an explicit representation of the goal is critical in boosting proactive control. It is discussed in terms of the mechanisms underlying this mode of control.

Keywords

proactive control; task switching; self-cueing strategies; goal setting; children

Highlights

- We examined the efficacy of two self-cueing strategies on children's use of proactive control
- Only kindergarteners and first graders benefited from self-cueing strategies

- Building an explicit representation of the goal ahead of stimulus processing enhance proactive control

1. Introduction

In a complex and ever-changing environment, cognitive control (also called executive control or executive function) defined as “the ability to regulate, coordinate and sequence thoughts and actions in accordance with internally maintained behavioral goals” (Braver, 2012) is critical. However, based on its very definition, the engagement of control relies on one’s goals. Without a goal to pursue, cognitive control becomes useless. It is now well documented that cognitive control develops considerably over the preschool period and beyond (Carlson, Davis, & Leach, 2005; Garon, Bryson, & Smith, 2008; Munakata, Snyder, & Chatham, 2012; Welsh, Nix, Blair, Bierman, & Nelson, 2010). Interestingly, children and especially kindergarteners have been shown to be prone to goal neglect (Marcovitch, Boseovski, Knapp, & Kane, 2010; Towse, Lewis, & Knowles, 2007) that is, a failure to behave according to the goal, despite knowing what the appropriate actions are (Duncan, Emslie, Williams, Johnson, & Freer, 1996). Hence, better identification and active maintenance of the goal to guide information processing during a task may be key factors in the development of cognitive control through childhood. However, whereas using environmental cues to set goals in advance may be highly adaptive in a reasonably predictable environment, young children have been shown to have specific difficulties in engaging control proactively (Chatham, Frank, & Munakata, 2009; Chevalier, Dauvier, & Blaye, 2018; Chevalier, Martis, Curran, & Munakata, 2015; Lucenet & Blaye, 2014). Hence, the present study investigated the benefit of inducing strategies requiring proactive processing of task cues on children’s goal setting in a task-switching paradigm. These strategies involved an explicit “translation” of an arbitrary task cue in advance of the target stimulus display.

1.1 Goal setting: a key aspect of cognitive control efficiency

Efficient cognitive control requires efficient goal setting. Goal setting itself involves identifying and actively maintaining task goals in working memory (Blair, Zelazo, & Greenberg, 2005; Braver, Gray, & Burgess, 2008; Friedman et al., 2008; Miller & Cohen, 2001; Munakata et al., 2012), and is proposed as the core component of cognitive control by several authors (e.g., Cragg & Chevalier, 2012; Friedman et al., 2008; Miyake & Friedman, 2012). This hypothesis is supported not only by structural analyses in adults (Friedman et al., 2008; Miyake et al., 2000) but also by studies in children and adults showing that manipulating the cost of goal setting (Blaye & Chevalier, 2011; Chevalier & Blaye, 2009) or of goal maintenance (Kane & Engle, 2003; Marcovitch et al., 2010) impacts control efficiency.

In one of the most widely-used control tasks in preschoolers, the Dimensional Change Card Sorting task (DCCS; Zelazo, Frye, & Rapus, 1996), participants have to sort bidimensional cards into two boxes, first according to one dimension *(e.g.,* color), and then, in a post-switch phase, according to the other (*e.g.,* shape). Most three-year-olds who succeed at applying each of the two rules independently, fail to switch to the second rule and perseverate in applying the pre-switch rule (e.g., Frye, Zelazo, & Palfai, 1995; Zelazo et al., 1996; see Doebel & Zelazo, 2015 for a review). This performance has been taken as evidence of the phenomenon of goal neglect (Marcovitch, Boseovski, & Knapp, 2007; Marcovitch et al., 2010; Towse et al., 2007). Marcovitch and colleagues' findings (Marcovitch et al., 2007; Marcovitch et al., 2010) have supported this hypothesis. The authors manipulated the relative proportion of conflict cards (in which, the two dimensions lead to opposite responses) and redundant cards (in which the two dimensions lead to the same correct responses) presented during the post-switch phase. Whereas conflict cards could serve as goal reminders, since sorting them requires a decision between two potential goals (sorting by color vs. sorting by shape), redundant cards may lead to goal neglect as sorting by either rule is compatible with both the pre- and post-switch goals. As expected considering the higher probability of goal neglect in the "mostly redundant" condition, preschoolers' performance on conflict cards was worse than in this condition than in the "mostly conflictual" one.

In older children and adults, the cued task-switching paradigm (Meiran, 1996) offers a specific measure to investigate the process of goal setting. This paradigm requires participants to sort bidimensional stimuli according to one or the other dimension in an unpredictable sequence. In contrast to the DCCS, however, sorting rules are not said verbally at the onset of each trial, but visual task cues are provided in advance of the stimulus display and specify which sorting task/goal is relevant for the current trial. Participants are presented with mixed-task blocks of trials in which they have to switch back-and-forth between the two tasks in an unpredictable way, based on the task cues. Two components of task-switching have been dissociated. Beyond the switching demand per se, goal setting, the ability to identify the relevant task goal and maintain it, can be assessed separately. The cost of goal setting (also called mixing cost) is measured by the difference between the mean performance in repeated trials in mixed-task blocks and the mean performance in single-task blocks. This difference is considered as good proxy for goal setting as neither of these two types of trial involves switching, and only the former requires selecting among two possible goals (Rubin & Meiran, 2005).

Lifespan studies independently examining the development of switching and goal setting have indicated a more pronounced inverted U-shaped developmental curve for mixing- than for switching costs (Cepeda, Kramer & Gonzalez de Sather, 2001; Kray, Eber, & Karbach, 2008; Kray, Eber, & Lindenberger, 2004; Lucenet, Blaye, Chevalier, & Kray, 2014; Reimers & Maylor, 2005). Similarly, in children, Karbach and Kray (2007) evidenced that mixing costs decreased significantly from 5 to 9 years of age while switching costs did not change between these ages (see also Chevalier et al., 2009; Chevalier, Blaye, Dufau, & Lucenet, 2010). The different developmental trajectories observed for the two costs with more drastic age-related changes for goal setting suggest that children's lower control performance may not so much lie in their lower switching abilities, but rather in their less efficient ability to identify and/or maintain the relevant task goal. The research reviewed so far supports the hypothesis of a benefit induced by self-cueing strategies that force children to systematically identify the goal.

The task-switching paradigm seems an appropriate context to test these strategies for two reasons: (a) goal setting is specifically demanding in this situation insofar as goal updating is required frequently and (b) the introduction of task cues ahead of stimulus onset makes the proactive activation of the relevant task-set based on the early identification of the goal highly adaptive (Rubin & Meiran, 2005). Indeed, updating one's goal is a necessary condition when unpredictable task switching may appear but updating it in advance, that is engaging control proactively, is even more adaptive. However, the recent literature on control development suggests that young children have specific difficulties in engaging control proactively.

1.2 Towards more proactive control with age

Optimal cognitive control relies on the ability to engage control at the right time. Braver and colleagues have developed the "dual mechanisms of control" theory (Braver et al., 2008) that distinguishes between two control modes depending on their temporal dynamics. Proactive control is engaged in advance of the control-demanding events (e.g., in task-switching: bidimensional stimuli to be sorted) and enables individuals to bias further processing, thus preventing conflicts before their onset. This mode of control is characterized by an early activation of goal-relevant information and by its active maintenance in working memory. On the contrary, reactive control is engaged late and transiently, only when confronted by the control-demanding event. Although it is less costly in terms of information maintenance, it allows conflicts to impact processing fully. Engaging control proactively in task switching consists in selecting the next appropriate goal based on task cues, ahead of the stimulus display. Subsequently, this mode of control implies performing the goal-relevant sorting at the stimulus onset. In contrast, reactive control engages self-questioning on which goal to pursue once the target stimulus is displayed.

Recent research has revealed a shift from reactive to proactive control during childhood, occurring around the time of the transition from kindergarten to elementary school (Blackwell, Cepeda & Munakata, 2009; Doebel et al., 2017; Gonthier, Zira, Colé, & Blaye, 2019; Lucenet & Blaye, 2014). This has been evidenced notably in task-switching situations. Chevalier et al. (2015) showed that contrary to school-aged children, preschoolers did not take advantage of a task-preparation delay (task cues presented in advance of the target stimulus) whenever they had an opportunity to process the cue after the stimulus onset. Similarly, Chevalier et al. (2018) highlighted a shift in the information prioritized by children between 3 and 12 years: Whereas preschoolers and children up to 8 years tended to consider the object to be acted on first, older children prioritized information from task cues (see also, Chevalier et al., 2010). Altogether, these findings illustrate younger children's difficulties in engaging proactive control in the context of task-switching where selecting the next goal to pursue is critical.

However, 5-year-old children have been shown to evidence proactive control in conditions where reactive control was made specifically difficult by making the cue disappear at stimulus onset (Chevalier et al., 2015). In other words, the predominant use of reactive control in preschoolers may not index an inability to engage control proactively, but rather a difficulty in monitoring when to engage more or less control (see also, Chevalier & Blaye, 2016). As a core component of proactive control is setting one's goal in advance, potential difficulties in translating contextual cues into goals must be overcome. Preschoolers' performances are specifically impacted by the degree of task-cue transparency in task switching (Chevalier & Blaye, 2008) and the detrimental effect of arbitrary cues only disappears gradually through childhood. Verbal self-cueing strategies may be a relevant way of supporting both an early translation of visual task cues into goals, and goal maintenance up to the target-stimulus display.

1.3 Improving cognitive control efficiency with verbal labeling

Since the initial work of Vygotsky (1962) and Luria (1969) on the regulatory function of language on child behavior, the role of verbal labels in cognitive control has been extensively investigated (for recent reviews, see Alderson-Day & Fernyhough, 2015; Cragg & Nation, 2010; Kray & Ferdinand, 2013). The detrimental effect of articulatory suppression in cognitive control tasks have been evidenced in 6- and 9-year-olds in tasks where memory demand was high (Fatzer & Roebers, 2012), with stronger effects in 9-year-olds, suggesting that performance in older children would more strongly rely on speech than younger children. In line with these findings, requesting children to verbalize task-relevant information out loud has shown to improve control-tasks performance (Fatzer & Roebers, 2013; Karbach & Kray, 2007; Kray et al., 2008; Kray, Gaspard, Karbach, & Blaye, 2013; Lucenet et al., 2014). More recently, Doebel, Dickerson, Hoover, & Munakata (2018) revealed that providing familiar labels for novel targets prior to completing a visual track facilitated preschoolers' performance as compared to when no labels were taught. Interestingly, most of these studies reported less pronounced beneficial effects of verbal labeling with age, while articulatory suppression led to more detrimental effects with age. Altogether, these findings support the hypothesis of a progressive internalization of self-regulatory speech into "inner speech" during mid-childhood (Winsler & Naglieri, 2003). Furthermore, age-related changes in the nature of the information verbalized have been evidenced. When required to "think aloud" in a task-switching paradigm, kindergarteners mainly verbalized their response while processing the target stimulus whereas 9-year-olds verbally translated the task cue in advance of stimulus display and then verbalized the response label (Karbach & Kray, 2007).

Despite the extended use of verbalizations to enhance self-regulation in children, one question that remains open and is the focus of the present study is the extent to which imposing a phonological format is critical. Verbalizing the cue aloud may support children's proactive control in task switching because it requires an explicit and meaningful goal representation to be built immediately after encoding the arbitrary goal cue, in advance of the upcoming stimulus (Chatham, Yerys, & Munakata, 2012; Munakata et al., 2012). Alternatively, what may be specific to the phonological format of the goal representation is that it can trigger a verbal rehearsal mechanism that may then enhance the level of activation of goal-relevant information up to the target stimulus display (Baddeley & Logie, 1999).

1.4 The present study

The aim of the present study is to investigate the extent to which requesting the labeling of goal-relevant information is critical per se or whether other ways of encouraging children to explicitly wonder about the goal ahead of processing stimuli can enhance their proactive control efficiency in a cued task-switching paradigm. Participants were presented with arbitrary task cues ahead of stimulus display. Two self-cueing strategies were contrasted, one that required children to verbalize the goal out loud and another that imposed to silently select among two explicit pictorial translations of the arbitrary goal cue. These two conditions of strategy induction were compared to a control condition, where children were asked to remain silent and were not encouraged to translate the arbitrary task cues in any way. Three age groups were enrolled from kindergarten to fourth grade. Improved goal-setting performance was expected in the two experimental conditions compared to the control condition. Comparison of goal-setting performance under the two strategy-cueing conditions was meant to highlight the potential specific benefits of requiring a verbal label of the upcoming goal. In line with previous studies, we hypothesized an improvement of goal setting with age and, more interestingly, a modulation of the benefits of the two self-cueing strategies by age.

More specifically, based on the development of proactive control from preschool years to mid-childhood, kindergarteners were expected to benefit from the induction of cueing strategies, while fourth graders who are already efficient in using proactive control should not be impacted. The effect of the self-cueing strategies in first graders remains an open question, as this age group is in the transition towards a more systematic use of proactive control.

2. Method

2.1. Participants

Participants included a sample of sixty kindergarteners (*M* = 5;10, range = 5;5–6;4, *SD* = 0;3, 46% female), sixty first graders (*M* = 6;10, range = 6; 5– 7;4, *SD* = 0;3, 46% female) and sixty fourth graders (*M* = 9;11, range = 9;5-10;4; *SD* = 0;3, 43% female). Children were all native French speakers and were recruited from five preschools and primary schools in the south of France. The children were predominantly Caucasian from middle-class families, reflecting the characteristics of the local community. Parental consents were obtained for all participants. In each age group, children were randomly assigned to one of the three conditions and were tested individually in a quiet room at their school. The comparability of the three experimental groups was assessed by the backward digit span (Wechsler, 2003). Mean scores within each age group did not significantly differ across conditions (all ps > 0.28).

2.2. Materials and Procedure

The task was adapted from the cued task-switching paradigm (Meiran, 1996). We used a DELL computer with a touch screen using E-prime software (Psychology Software Tools, Inc., 2007) for stimulus presentation and data collection. Visual stimuli consisted of thirty-six colored line drawings of animals (i.e., three different dogs and three different birds presented in three different shades of green and three different shades of red).

The participants were instructed to perform two different tasks, an "animal" task (task A) and a "color" task, corresponding to the two possible ways of sorting the stimuli. In the animal task, participants were asked to decide whether the animal was a dog or a bird. In the color task, they had to decide whether the picture was colored in red or green. Four response options were displayed in the lower half of the screen. Response options corresponded to two black and white line drawings of animals (dogs and birds) and two patches of colors (red and green) all different from the actual stimuli used in the experiment (see Fig. 1). Before the experiment, the stimuli were presented individually to the children to ensure that they were able to correctly identify each animal and then, each color used in the experiment. All the children succeeded. The display of response options was constant across subjects and conditions.

In single-task blocks, participants were instructed to perform either task A or task B. In mixed-task blocks, they were asked to switch between tasks A and B. Arbitrary task cues were presented in advance of stimulus display to index the task to perform on the upcoming trial. They consisted of either one or two black dots (5 mm in diameter). The meaning of cues was counterbalanced across participants. To ensure that children were not confused about cue meanings and maintained cue-task associations, cue questions were asked (which task was associated with which cue) before starting test trials, and at the end of the experiment. All the children successfully recalled the cue meanings on both occurrences. Children were tested in one of three conditions (control, goal labeling, goal pointing). In the control condition, children were asked to remain silent. In the goal-labeling condition, they were instructed to name the next task to be performed when the arbitrary cue appeared on the screen and before target presentation. In the goal-pointing condition, they were required to silently press one of the two transparent pictorial representations of the task goal depicting an imaginary animal or a paint palette to index the animal and color tasks, respectively (see Fig. 1).

In all conditions, the experiment was divided into a training phase and an experimental phase. The training phase consisted of 9 trials (2 animal trials, 2 color trials and 5 mixed trials). All the children succeeded in at least 8 of the 9 training trials. The experimental phase consisted of two sessions of 4 blocks. Each session included two single-task blocks (one animal and one color task) followed by two mixed-task blocks. Except for training trials, no feedback was delivered.

Each block consisted of 17 trials, yielding a total of 17 × 8 = 136 experimental trials per condition. The single and mixed-task blocks consisted of an equal number of four stimulus types (dog/in red, dog/in green, bird/in red, bird/in green). In addition, mixed-task blocks consisted of an equal number of non-switch and switch trials, and the animal and color tasks were alternated pseudo randomly (i.e., not more than three switch trials in a row)

In single-task blocks, each trial started with the presentation of a fixation cross at the top center of the screen for 1000 ms, followed by the simultaneous presentation of the arbitrary cue at the top center of the screen and a meaningless white rectangle at the center of the screen. Children were required to press on the rectangle as soon as they had seen which task to perform, which triggered the stimulus presentation and made the arbitrary cue disappear. The four response options appeared simultaneously 500 ms after stimulus onset and remained on the screen until a finger press was registered. This delay was meant to encourage the children to process the target stimulus before entering a response. The target stimulus and response options remained visible on the screen until a response was made. The time interval between the response and the next fixation cross was 25 ms (see Fig. 1.a).

In mixed-task blocks, the trial sequence varied according to conditions. In the control condition, the trial sequence was identical to the single-task blocks (see Fig. 1.a). In the goal-labeling condition, children were instructed to name the task goal once the arbitrary cue appeared together with a rectangle which they had to press as soon as they labeled the goal (see Fig. 1.a). This finger press in turn triggered the stimulus presentation and then the four response options. In the goal-pointing condition, the arbitrary cue appeared together with two transparent cues consisting of visual representations of the goals (i.e., an imaginary animal for the animal task and a multicolored template for the color task). These transparent cues were presented in the center of the screen (see Fig. 1.b). Both the arbitrary cue and the two potential transparent translations remained on the screen until children press the transparent cue corresponding to the correct task goal, which, in turn, triggered the display of the stimulus, and then the four response options. In order to maximize the use of proactive control in all conditions, arbitrary cues were removed from the screen as soon as the stimulus appeared.

Participants were instructed to respond as quickly and as accurately as possible. Verbal instructions were provided before each of the experimental blocks, indicating whether the animal task, the color task or both tasks had to be performed. After 4 blocks, subjects had a short break of 5 minutes.

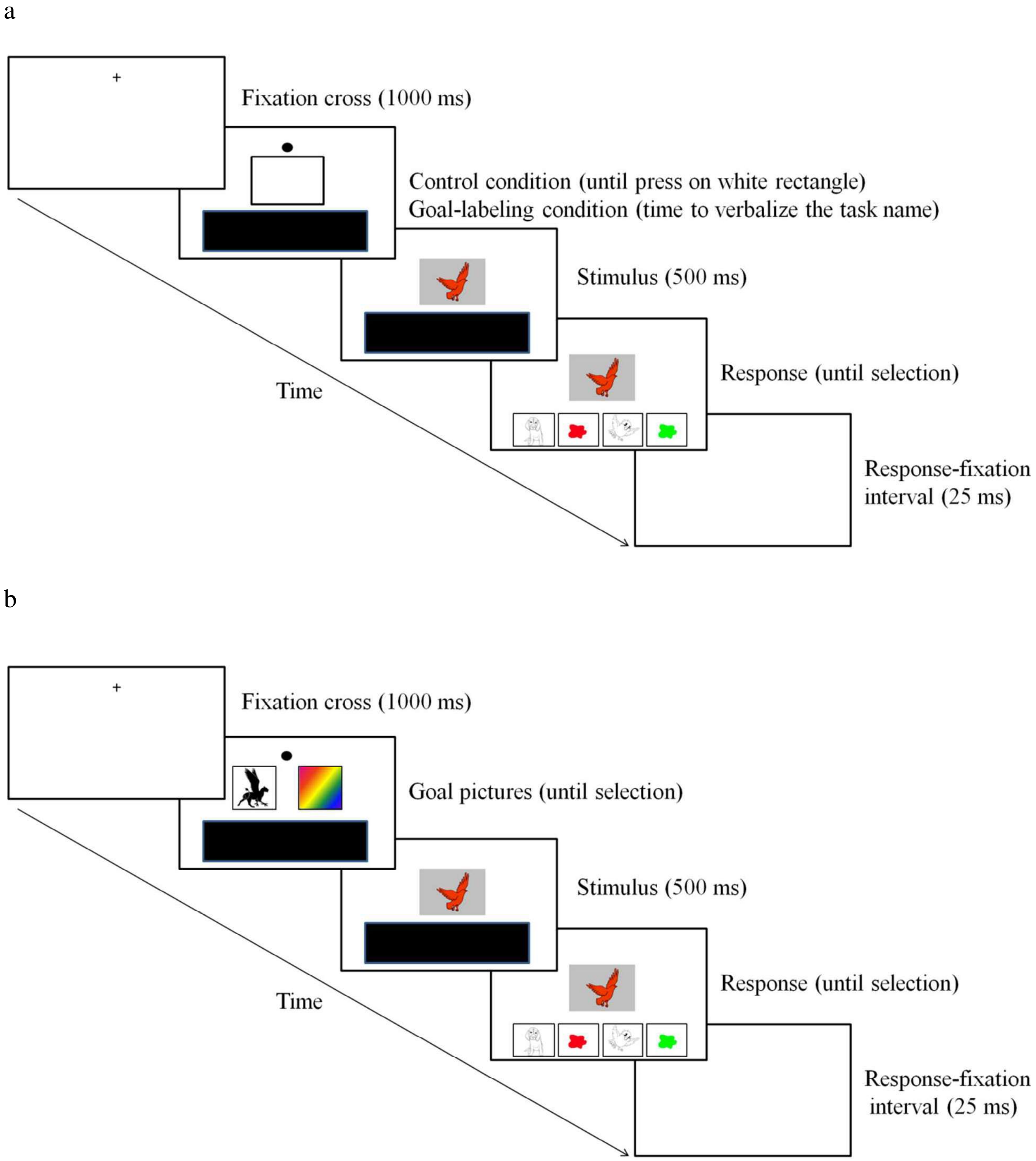

Fig. 1. Illustration of within-trial sequences, a- in single-task blocks for all conditions and in mixed-task blocks in the control and goal-labeling conditions, b- in mixed-task blocks in the goal-pointing condition.

3. Results

In the experimental blocks, the first trial of each block was excluded from analysis. Trials with correct response times (RTs) lower than 200 ms or above 2 standard deviations from each participant's mean response time for each trial type were also discarded from analyses (3.7% of trials for kindergarteners, 3.2% of trials for first graders, 3.9% of trials for fourth graders). Data from twelve children were excluded (three kindergarteners, seven first graders, two fourth graders) because of uncooperativeness or unusually high error rates in single trials (beyond 25% of errors).

Two analyses of variance (ANOVA) were run on error rates and correct response times respectively with Grade Level (kindergarteners, first graders, fourth graders) and Condition (control, goal labeling, goal pointing) as between-subject factors and Trial Type (single, no switch, switch) as a within-subject factor. To control for baseline differences in RTs among age groups, all RT analyses were conducted with RTs transformed to their natural logarithm (following Meiran, 1996). The results of the ANOVAs on mean error rates and RTs are presented Table 1 and Table 2 in Appendix A. For the sake of clarity, reported values were back transformed (see Table 3 in Appendix B for the error rates and RT means from all conditions and trial types in the three grade levels). Planned contrasts were performed to test our hypotheses about interaction effects between condition, trial type and grade level. In order to explore other potentially significant results, post-hoc tests were also employed and, where appropriate, used the Bonferroni adjustment for multiple comparisons.

The analysis revealed grade-level effects on error rates and RTs, F (2,159) = 25.71, $p <$ 0.0001, $\eta_p^2 = 0.24$, and F (2,159) = 134.8, p < 0.0001, $\eta p^2 = 0.62$, respectively. A Bonferroni post-hoc test revealed that error rates decreased from kindergarteners (M = 12.8%) to fourth graders (M = 4.9%), $p < 0.0001$, but did not differ between kindergarteners and first graders (M = 10.8% in first graders, p = 0.32). Turning to RTs, a similar test revealed significant differences between all grade levels [fourth graders (M = 901 ms) < first graders (M = 1517 ms) < kindergarteners (M = 1945 ms) all ps < 0.0001]. A significant main effect of trial type was also found on error rates, F (2,318) = 69.31, p < 0.0001, η_p^2 = 0.30, and on RTs, F (2,318) = 96.5, p < 0.0001, ηp^2 = 0.37. In addition, a Grade Level × Trial type interaction was obtained for error rates $F(4,318)$ =5.61, p <.001, η_p^2 = 0.06; this interaction was itself qualified by Condition. The three-way interaction was significant for error rates too, F (8, 318) = 2.16, p< 0.05, η_p^2 = 0.05, (see Fig. 2) and will be discussed below. These last two interactions were not significant for RTs (all ps > 0.40). Due to the low sensitivity of this dependent variable in this age range (Doebel et al., 2017; Tamnes, Fjell, Westlye, Ostby, & Walhovd, 2012), RTs were not considered further. As our hypotheses focused on goal-setting efficiency that is indexed by mixing cost, these interactions were investigated further by examining the contrasts between performance on single and non-switch trials (see Fig. 2).

Benefit of self-cueing strategies on goal setting

Overall mixing costs were significant (M = 6.6%; $F(1,159)$ = 54.53, p < 0.0001, η_p^2 = 0.25) and decreased with grade level (kindergarteners: M = 9,9% vs. first graders: M = 5,6% vs. fourth graders: M = 4%; $F(2,159)$ = 4.02, p < 0.05. In kindergarteners, mixing costs were significantly smaller in the two cueing conditions (goal labeling: M = 3.6% vs. goal pointing: M = 9.2%), than in the control one (control: M = 17.1%); $F(1,159)$ = 13.67, p < 0.001, η_p^2 = 0.07, for the difference between control vs. goal labeling; F (1,159) = 4.80, p < 0.05, η_p^2 = 0.02, for the difference between control vs. goal pointing. These two cueing conditions did not differ (p > 0.15). The same pattern of performance was obtained in first graders: mixing costs decreased from control (M =11.1%) to goal labeling (M = 2%), $F(1,159)$ = 5.29, p < 0.01, η_p^2 = 0.03, and from control to goal pointing (M = 3.6%), $F(1,159)$ = 4.14, p < 0.05, η_p^2 = 0.02. Goal-labeling and goal-pointing conditions did not differ (p = 0.69). Turning to fourth graders, mixing costs did not differ across conditions (all *p*s > 0.62). As our hypothesis was precisely a null effect of condition on mixing costs in this grade level, we run a Bayesian analysis to test evidence in favor of this hypothesis. The statistical software JASP was used (JASP Team, 2017) to compute the Bayes Factor. Results showed positive evidence (Jeffreys, 1961) for a lack of effect ($BF_{01}=5.61$).

It is worth noting, as illustrated in Figure 2, that the mixing costs of kindergarteners and first graders in the goal-labeling condition (kindergarteners: $M = 3.6\%$, and first graders: $M = 2\%$) reached the size of the mixing cost observed in fourth graders in the control condition ($M = 3.4\ \%$), $p > 0.69$. Considering the pointing condition, although mixing costs were descriptively higher for kindergarteners ($M = 9\%$, but first graders: $M = 3.6\%$), the differences between mixing costs in fourth graders ($M = 5.3\%$) remained non-significant (all *p*s > 0.31).

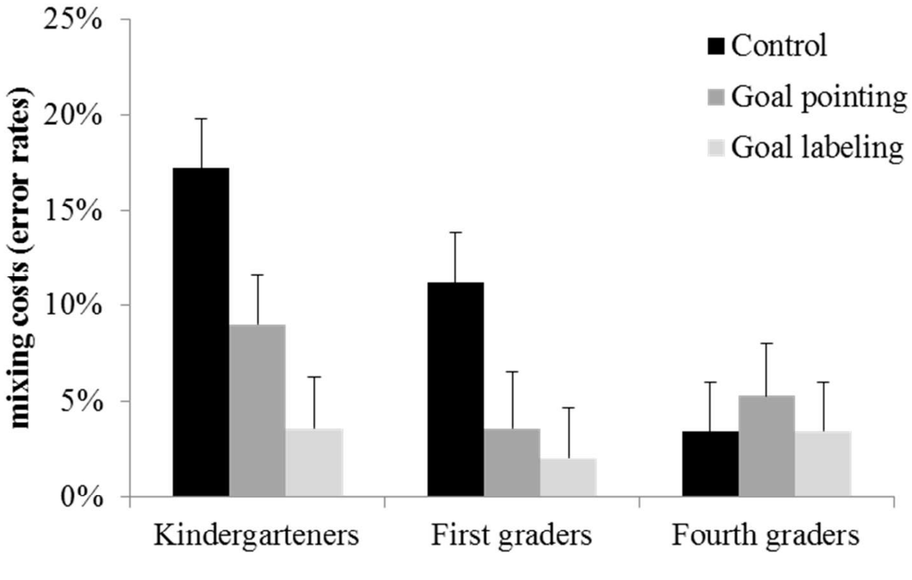

Fig. 2. Mixing costs (on error rates) as a function of grade level (kindergarteners, first graders, fourth graders) and condition (control, goal labeling, goal pointing). Error bars refer to the standard errors of the means.

4. Discussion

This study assessed the potential age-related effects of two self-cueing strategies in children's efficiency at setting goals proactively while switching between tasks. These strategies consisted of labeling the goal or pointing to the relevant transparent representation of the goal to explicitly translate the displayed arbitrary task cue. The design we used maximized the necessity to translate the cue into an explicit representation as it disappeared as soon as the stimulus was presented, making it impossible to turn back to the cue after the stimulus display (Chevalier et al., 2015). More efficient proactive control in this context should translate into easier goal setting indexed by lower mixing costs.

In line with recent findings revealing increasing efficiency of proactive control from preschool to school-age and even beyond (Chevalier, James, Wiebe, Nelson, & Espy, 2014; Chevalier et al., 2015; Elke & Wiebe, 2017; Lorsbach & Reimer, 2008; 2010; Lucenet & Blaye, 2014), a significant improvement in goal setting across the three age groups was found. Furthermore, the two self-cueing strategies improved proactive control in kindergarteners, and first graders, but not in fourth graders. The lack of benefit in fourth graders, which was expected, suggests that children at this age already spontaneously use such strategies, at least in a context that encourages proactive goal setting, or do not need them anymore. This last result may appear inconsistent with previous studies revealing a beneficial effect of verbal labeling in task switching in school-aged children and adults (Karbach & Kray, 2007; Kray et al., 2008; Kray, Lucenet, & Blaye, 2010; Lucenet et al., 2014). However, a common feature of these studies is that the participants had to verbalize while the target was already displayed. In such a context, the currently irrelevant dimension of the target may create a conflict both with the relevant one and with the information carried out by the task cue, which is implicitly to ignore this dimension. Labeling may then be critical in older children to overcome such a conflict, absent in the design of the current study.

Interestingly, the benefits induced by the two strategies in the younger age groups suggest that the imposed format of translation of the arbitrary task cue does not need to be verbal to support goal setting. In other words, retrieving an explicit representation of the goal, may it be verbal or pictorial, in advance of the upcoming stimulus has favored goal setting for the two younger age groups. Although the hypothesis that some children in the goal-pointing condition might in turn have verbally translated the transparent pictorial representation of the arbitrary task-cue cannot be directly disproven, a number of arguments go against this hypothesis. First, as recalled in a recent review (Alderson-Day & Fernyhough, 2015), inner speech follows a protracted development until mid-childhood, and should still be immature in kindergarteners and first graders. Considering that participants in the control and goal-pointing conditions were requested to perform the task in silence, verbal labeling of the goal, if produced, was necessarily subvocal. Further, the pictorial representations of the goals used in the goal-pointing condition were not associated to familiar labels, at least for young children (i.e., a chimaera for shape and a multicolored template within a square for color), and were never named by the experimenter during the entire procedure making it unlikely that children in this condition used verbal labeling and in any case, used it more often than children in the control condition who could potentially label the arbitrary cues.

Despite the implausibility of the use of verbal labels in the goal-pointing condition, the data failed to reveal a significant superiority of the verbal cueing strategy (goal-labeling condition) on the pictorial one. The hypothesis of a possible induction of verbal rehearsal of the goal after having labeled the cue is thus not supported.

It should be noted that the benefits induced by the two self-cueing strategies brought kindergarteners and first graders up to the goal setting performance of the older age group, supporting the hypothesis that proactive control is already part of the kindergartener’s repertoire of control modes (Chevalier, 2015; Elke & Wiebe, 2017). The present findings also suggest that even in a context encouraging its use, proactive control is not optimally engaged in these age groups if not scaffolded. A possible alternative explanation for the reduction of the goal-setting cost in the experimental conditions could be that the two self-cueing conditions simply gave the younger children more time to process the cue. However, this alternative explanation is not supported by the data[1].

Considering what the two induced strategies commonly imposed on children's performance, sheds new light on the possible reasons why setting goals proactively is particularly challenging for kindergarteners and first graders. One possibility is that young children encounter difficulties at the arbitrary cue processing stage. However, the low error rates associated with goal identification in goal labeling and goal pointing in the two younger age groups (<5%) suggest that they are already able to represent the goal explicitly on the basis of the displayed cue. Hence, difficulties do not seem to be related to the task-cue translation *per se*. Indeed, the developmental literature on task-switching has shown that contrary to older children and adults who consider task cues before turning to the target stimuli, young children tend to prioritize stimuli that is, the objects they have to respond to (e.g., Chevalier et al., 2010; Chevalier et al., 2018). As these authors suggested (Chevalier & Blaye, 2016; Chevalier et al., 2015; Chevalier et al., 2016), such a non-optimal sequencing of processing operations may be related to a lack of metacognitive monitoring of cognitive control. Young children's difficulty at processing the task cue in advance and their tendency to wait for the stimulus and only then, reactively retrieve the immediate preceding cue to decide which task set is relevant might have been overcome in the present study by the

[1] We thank an anonymous reviewer for this suggestion. An analysis of covariance (ANCOVA) on mixing costs was run with the latency between cue- and stimulus display (CSI) as a covariate and Condition and Grade Level as categorical predictors. The main effect of the covariate was not significant ($p > 0.24$) and including this variable did not modify the interaction between condition and grade level.

induced strategies. Indeed, both strategies have in common to relieve children from deciding the optimal sequence of cue and target processing in requesting first a response following the arbitrary task cue and then a response to the target stimulus. Requiring a response to the cue makes children wonder about the goal in advance of the stimulus and hence potentially activate the relevant task-set. In other words, this study revealed that strategies based on a characteristic feature of reactive control, namely prioritizing objects one has to respond to, are efficient at promoting better proactive control. As such, it provides a new illustration of the benefit of building new induced strategies on what children already do.

5. Conclusions

The present findings offer new suggestions about the underpinnings of young children's low proactive control and how it can be scaffolded. Requesting verbal labeling of the goal is not a unique way to support proactive goal setting in young children. What seems critical is (a) to encourage young children to build an explicit representation of the goal in advance of the target to respond to, and (b) to do so by anchoring the induced strategy on the characteristic feature of their usual reactive control. In revealing that cue pointing at the right time might scaffold a proactive mode of control, this study offers new paths for clinical practice with populations presenting executive deficits and poor, or a lack of, verbal abilities (e.g. autism, Whitehouse, Maybery, & Durkin, 2006).

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Appendix A

Source	Sum of squares	df	Mean square	f-ratio	P	η_p^2
Grade Level	0,566	2	0.283	25.716	0.000	0.24
Condition	0.115	2	0.057	5.242	0.006	0.06
Grade Level*Condition	0.201	4	0.050	4.568	0.001	0.10
Error	1.749	159	0.011			
Trial type	0.835	2	0.417	69.313	0.000	0.30
Trial type*Grade Level	0.135	4	0.033	5.618	0.000	0.06
Trial type*Condition	0.087	4	0.021	3.646	0.006	0.04
Trial type*Grade Level*Condition	0.104	8	0.013	2.164	0.029	0.05
Error	1.917	318	0.006			

Table 1. Summary table of analysis of variance performed on the mean error rates

Source	Sum of squares	df	Mean square	f-ratio	P	η_p^2
Grade Level	45.68	2	22.84	134.8	0.000	0.62
Condition	0.60	2	0.30	1.8	0.173	0.02
Grade Level*Condition	1.41	4	0.35	2.1	0.085	0.04
Error	26.94	159	0.17			
Trial type	5.56	2	2.78	96.5	0.000	0.37
Trial type*Grade Level	0.07	4	0.02	0.6	0.660	0.007
Trial type*Condition	0.34	4	0.09	3.0	0.019	0.03
Trial type*Grade Level*Condition	0.24	8	0.03	1.0	0.405	0.02
Error	9.16	318	0.03			

Table 2. Summary table of analysis of variance performed on the mean RTs transformed to their natural logarithm

Appendix B

	Control	Goal pointing	Goal labeling
Trial type	*M (SD)*	*M (SD)*	*M (SD)*
		Kindergarteners	
Single	5.31 (5.83)	6.94 (7.07)	4.27 (4.19)
	1679 (674)	1663 (564)	1618 (415)
Non-switch	22.5 (16.01)	15.97 (9.64)	7.89 (9.51)
	1929 (787)	2192 (561)	2017 (693)
Switch	22.81 (13.5)	18.05 (9.79)	11.51 (8.90)
	1939 (832)	2234 (612)	2236 (952)
		First graders	
Single	5.59 (8.04)	4.60 (5.03)	4.16 (5.62)
	1237 (330)	1327 (363)	1132 (314)
Non-switch	16.77 (15.03)	8.22 (7.23)	6.25 (5.78)
	1512 (531)	1837 (503)	1535 (465)
Switch	17.43 (13.27)	19.40 (11.57)	15 (8.11)
	1558 (609)	1975 (668)	1535 (441)
		Fourth graders	
Single	1.56 (4.91)	1.87 (5.00)	2.43 (3.79)
	825 (191)	764 (160)	732 (184)
Non-switch	5.00 (7.47)	7.18 (6.49)	5.90 (6.59)
	1039 (194)	875 (188)	986 (233)
Switch	4.37 (6.11)	6.25 (5.73)	10.41 (8.02)
	984 (212)	947 (230)	957 (215)

Table 3. Mean scores on error rates and RTs (ms) as a function of Grade Level and Condition (with standard deviations in parentheses)