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Language and Executive Functioning: Children's Benefit from Induced Verbal Strategies in Different Tasks

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Abstract

The interplay of language and cognition in children's development has been subject to research for a long time. The present study followed up on recently reported deleterious effects of articulatory suppression on children's executive functioning (Fatzer & Roebers, 2012), aiming to provide more empirical evidence on the differential influence of language on executive functioning. In the present study, verbal strategies were induced in three executive functioning tasks. The tasks were linked to the three central executive functioning dimensions of updating (Complex Span task), shifting (Cognitive Flexibility task) and inhibition (Flanker task). It was expected that the effects of the verbal strategy instruction would counter the results of articulatory suppression and thus be strong in the Complex Span task, weak but present in the Cognitive Flexibility task and small or nonexistent in the Flanker task. $N = 117$ children participated in the study, with $n = 39$ four-year-olds, $n = 38$ six-year-olds, and $n = 40$ nine-year-olds. As expected, results revealed a benefit from induced verbal strategies in the Complex Span and the Cognitive Flexibility task, but not in the Flanker task. The positive effect of strategy instruction declined with increasing age, pointing to more frequent spontaneous and self-initiated use of verbal strategies over the course of development. The effect of strategy instruction in the Cognitive Flexibility task was unexpectedly strong in the light of the only small detrimental effect of articulatory suppression in the preceding study. Implications for language's involvement in the different executive functioning dimensions and for practice are discussed.

Keywords: executive functions, language, verbal strategies, children

1. Introduction

1.1 Study Aims

The relation of language and cognition has a long tradition in developmental research (Vygotsky, 1934/1962). Recently, research in this area focuses on executive functioning (EF) as a highly relevant construct of cognition (Best & Miller, 2010). Executive functions are defined as processes allowing for flexible and goal-directed behavior in new situations. Updating, shifting and inhibition have been identified as central EF processes (Miyake & Friedman, 2012). The contribution of language to EF and its development has been studied using various approaches, such as the examination of EF in individuals with specific language characteristics (e.g., bilinguals), and experimental approaches using observation of spontaneous speech, labeling, or articulatory suppression under investigation (for a review see Cragg & Nation, 2010). In the present study, we built on a recent study, in which language's involvement in children's EF was assessed through articulatory suppression (Fatzer & Roebers, 2012). In the present approach, verbal strategies were induced on the same EF tasks and in the same age groups (six- and nine-year-olds). This allowed addressing the question whether the documented effects of verbal strategy instruction counter the effect of articulatory suppression on EF performance, and more generally whether language has the potential to fuel developmental progression in different EF dimensions. Furthermore, it is of educational and practical relevance to know which cognitive processes can be supported by instruction of verbal strategies.

1.2 The Contribution of Language to the Different Executive Functioning Dimensions

1.2.1 Updating

The central EF dimension of updating is defined as dynamic manipulation of the contents of working memory (WM), which involves short-term storage and recall, as well as a simultaneous processing of information (Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). In the context of strategy development research, a strong relation between verbal strategies (labeling and rehearsal) and short-term recall was found, with children of seven years typically beginning to use verbal strategies in simple tasks (Flavell, Beach, & Chinsky, 1966). Articulatory suppression studies furthermore revealed that memory performance in older children and adults strongly relied on these verbal strategies or inner speech (e.g., Hitch et al., 1983). Likewise, Fatzer and Roebers (2012) found that articulatory suppression had a strong detrimental effect on performance in a complex span task which interacted with age, as the detrimental effect was stronger in the nine-year-olds than in the six-year-olds. In fact, the difference between performance under articulatory suppression and a baseline condition was only marginally significant in the six-year-olds, as was the difference between the articulatory suppression condition and the foot tapping condition. On the other hand, the nine-year-olds' performance decreased to the level of the six-year-olds' baseline performance under articulatory suppression, indicating that verbal strategies are crucial to the developmental progression observed between the age groups. Still, the small effect of articulatory suppression in the six-year-olds prompted us to include a third age group of even younger children in the present study. In previous studies, it was found that performance of younger children who do not spontaneously use verbal strategies can be markedly improved by simple strategy instruction (Hitch, Halliday, Schaafstal, & Hefernan, 1991; Keeney, Cannizzo, & Flavell, 1967). Based on these findings, we expected the strategy instruction in the present study to have a very strong effect in the four-year-olds, a strong effect in the six-year-olds, and a weak or nonexistent effect in the nine-year-olds.

1.2.2 Shifting

The central EF dimension of shifting, or cognitive flexibility, is defined as "shifting back and forth between multiple tasks, operations, or mental sets" (p. 55, Miyake et al., 2000). There are two versions of the task-switching paradigm; one with predictable task sequences (alternating and alternating-runs versions) and one with unpredictable task sequences (the cueing procedure). In adults, articulatory suppression had a detrimental, but not a debilitating, effect on performance in both versions (e.g., Emerson & Miyake, 2003; Miyake, Emerson, Padilla, & Ahn, 2004). The cognitive flexibility task used in Fatzer and Roebers (2012) involved aspects of the alternating switching paradigm. Articulatory suppression had a small detrimental effect on performance. This effect did not interact with age, although it appeared that performance was more strongly impaired in the older children compared to the younger children on the descriptive level (15% accuracy versus 6% accuracy, respectively), suggesting more spontaneous speech use in the older children. Moreover, the developmental progression between the six-year-olds and the nine-year-olds in shifting could not be fully attributed to the contribution of inner speech, as the difference in performance levels between the age groups was larger than the impairment of articulatory suppression. In another study, in which the contribution of language to shifting was estimated by induced labeling, a beneficial effect was found on performance in the alternating-runs version, with this effect decreasing with increasing age (seven- to nine- versus eleven- to thirteen-year-olds; Kray, Eber, & Karbach, 2008). The same developmental trend was also found for the cueing procedure (e.g., Chevalier & Blaye, 2009). Thus for the present study, we expected a small effect of the verbal strategy instruction that would possibly decrease with increasing age. Although the six-year-olds in Fatzer and Roebers showed a slight impairment under articulatory suppression, percent accuracy in the 6-year-olds and piloting revealed that the task was too difficult for four-year-old children. Thus, the cognitive flexibility task was only conducted with the two older age groups.

1.2.3 Inhibition

The EF dimension of inhibition is defined as the "ability to deliberately inhibit dominant, automatic, or prepotent responses when necessary" (p. 57, Miyake et al., 2000). There are only a few studies focusing on language's contribution to inhibition. An articulatory suppression study showed that language supported performance in adults; however, the effect was not attributable to inhibition itself, but rather to goal maintenance under highly demanding situations (Saeki, 2007). In another study, Kray, Kipp, and Karbach (2009) found that labeling the stimulus, but not labeling the demanded action (stop or go), improved performance in a selective inhibition task. The effect was strongest in the youngest children included in the study (seven- to nine-year-olds). Thus, it seems that language may at best have an indirect effect on inhibition, potentially by strengthening mental representations of task-relevant aspects when interference is high. Müller, Zelazo, Hood, Leone, and Rohrer

(2004) did find an enhancing effect of induced labeling on interference control in four-year-olds. In the study by Fatzer and Roebers (2012), an adapted version of the Flanker paradigm was used to measure interference control. In contrast to Müller et al. however, no specific effect of articulatory suppression was found, but rather a general effect of dual-tasking. Thus, speech or verbal strategies can be considered as unlikely in fueling developmental progression in this task, and therefore it was expected that the induced labeling would not effect six- and nine-year-olds' performance in the present study. Nevertheless, based on Müller et al.'s finding together with the consideration that four-year-olds experience greater difficulty with controlling interference than older children (Davidson, Amso, Anderson, & Diamond, 2006), possibly making them more reliant on speech (Fernyhough & Fradley, 2005), we conducted the Flanker task with four-year-olds to investigate whether language would contribute to interference control early in EF development.

1.3 Hypotheses

Taken together, we expected that the performance-enhancing effect of the verbal strategy instructions would be strong in the Complex Span task, present in the Cognitive Flexibility task, and weak or nonexistent in the Flanker task. Furthermore, it was expected that the positive effect of the induced verbal strategies on performance would decrease with increasing age, because of older children's more frequent spontaneous use of verbal support in these tasks.

2. Method

2.1 Participants

Of N = 124 participating children, n = 7 children had to be excluded because of outliers, incomplete data, or failure in strategy application in the Complex Span task or the Cognitive Flexibility task. Because a number of children (n = 12) did not apply the instructed strategy in the Flanker task, these children were excluded for analyses of the Flanker task only. Piloting furthermore revealed that the Cognitive Flexibility task was too difficult for 4-year-olds (performing at chance level, with the task being interrupted after every second trial) and the Cognitive Flexibility task therefore was only administered to the participating 6- and 9-year-olds. The final sample comprised N = 117 children. Thereof, n = 39 children constituted the age group of 4-year-olds (62% girls; M = 56 months, SD = 2.9 months, range: 50 – 60 months), n = 38 children constituted the age group of 6-year-olds (34% girls; M = 77 months, SD = 3.3 months, range: 72 – 84 months), and n = 40 children constituted the age group of 9-year-olds (35% girls; M = 115 months, SD = 3.1 months, range: 109 – 120 months). The 4-year-old children attended the first year of Kindergarten, the 6-year-olds the second year of Kindergarten, and the 9-year-olds attended the third grade of primary school. Half of the children were assigned to the verbal-strategy group (VSG; n = 19 4-year-olds [63% girls], n = 19 6-year-olds [47% girls], n = 18 9-year-olds [39% girls]), and half of the children to the control group (CG; n = 20 4-year-olds [60% girls], n = 19 6-year-olds [21% girls], n = 22 9-year-olds [32% girls]). Separate analyses for the three age groups revealed no differences for age in months between the verbal-strategy group and the control group, $F < 3$, and between sexes, $F < 3$. Children were recruited from public institutions in rural and urban parts of Switzerland. Only children with written parental consent were included.

2.2 Apparatus

All tasks were programmed and run using E-Prime software (Psychology Software Tools, PST, Pittsburgh, PA). Accuracy and response latencies were recorded with two external buttons, interfaced to the computer via a serial response box.

2.3 Executive Functioning Tasks

2.3.1 Complex Span Task

The Complex Span task is a WM task that requires participants' simultaneous storing and processing of stimuli (Pickering & Gathercole, 2001). A trial of our Complex Span task consisted of the serial presentation of red or blue two-syllable objects. As processing component, participants had to judge the objects' color on its presentation by pressing the corresponding button. At the end of each trial, participants were asked to recall the objects in correct order. After instruction and practice trials, the task started with trials of two objects. If participants correctly recalled at least three trials, one object was added after six trials, with five objects being the maximum. The total number of correctly recalled trials was used as the dependent variable.

2.3.2 Cognitive Flexibility Task

Cognitive flexibility was assessed by using an adaption of a task by Zimmermann, Gondan and Fimm (2002). This Cognitive Flexibility task required participants to flexibly shift between two alternating task rules, without

cues being provided. Two categories of fish were simultaneously presented on screen. Participants were told to alternatingly distribute food between two fish families by pressing the left or right button, depending on the fish's local appearance on screen. There were trials with a response set switch (switch trials) and trials without a response set switch (non-switch trials). Non-switch trials referred to trials in which the two kinds of fish appeared on the same sides as in the previous trial, thus answering in a left-right manner was correct. This answering scheme (left-right-left-right) was established as prepotent motor response scheme through the instruction and practice trials. In switch trials, the two kinds of fish changed sides compared to the previous trial, so that the right answer was to press the same button as in the previous trial. Thus, inhibiting the prepotent motor response as well as updating the relevant task rule was inevitable for correct responding in switch trials. Mean accuracies of responses in switch trials served as the dependent variable. After false responses, a visual sign occurred, indicating on which side to continue. The task consisted of 20 trials (excluding practice trials) and interstimulus intervals varied from 300 to 700 msec.

2.3.3 Flanker Task

To measure interference control, a child-appropriate version of the Erikson-Flanker-Paradigm (Eriksen & Eriksen, 1974) was used. In this Flanker task, participants were asked to respond to the orientation of a target stimulus (a fish centered on screen) by pressing the left or right button as quickly as possible. After a block of $n = 12$ congruent trials (flanking fish pointing into the same direction as the target fish), referred to as baseline trials, a mixed block of $n = 36$ trials followed. The mixed block consisted of $n = 12$ congruent, $n = 12$ incongruent (flanking fish pointing into the opposite direction as the target fish), and $n = 12$ neutral (six trials with flanking starfish and six trials containing only the target fish) trials in random order. All trials were separated by a central fixation cross. Interstimulus intervals varied between 800 and 1400 msec. An interference score was calculated from the mean reaction time in the baseline trials and the incongruent trials [(incongruent – baseline) / baseline], serving as the dependent variable.

2.4 Experimental Manipulation

Participants in the verbal-strategy group were instructed to loudly use a task-specific verbal strategy. In the Complex Span task, children were instructed to use labeling or cumulative rehearsal. Labeling (naming the object on its appearance) was shown before cumulative rehearsal (repeating the names of the previous objects first and then add the name of the currently presented object). The use of cumulative rehearsal was optional. For the Cognitive Flexibility task, a verbal strategy supporting the process of self-cuing was induced in order to facilitate switching between the two rules. Participants were instructed to alternately say "colored-plain" or any other words they wanted to use (e.g., "with-without"). In the Flanker task, the verbal strategy also consisted of verbalizing the rule. Children were instructed to say "middle" on presentation of the target stimulus. Each verbal strategy was first demonstrated by the experimenter and then briefly practiced by the participants. The experimenter monitored the application of the verbal strategy and any deviation from the instruction was documented.

2.5 Procedure

Participants were tested individually in a separate room at their institution, with testing sessions lasting about thirty minutes. Each task was performed twice in consecution: 1) baseline trial (BT) and 2) experimental trial (ET). The experimenter closely watched each child during their performance in the baseline trial and filled in a short questionnaire concerning the spontaneous verbalizations of the child. Verbalizations were classified as inconsistent when they occurred in an unsystematic manner in some trials during the performance, or they were classified as consistent when they were shown in a systematic manner during most parts of the performance. No differences in the frequency of verbalizations were found between the verbal strategy group and the control group in each age group, $\Pi^2 < 3$. Participants in the verbal-strategy group were instructed to use the corresponding verbal strategy after the baseline trials, whereas participants in the control group received the encouragement to complete the same task a second time. Task order was counterbalanced across participants. Each child received a small gift for participating.

3. Results

3.1 Preliminary Analyses

Sex was not included as between-subjects factor, because there were no significant differences between boys and girls in any of the dependent variables. Level of significance was $p < .001$, if not otherwise reported. Partial eta^2 (η_p^2) is reported as estimator of effect size.

3.2 Effects of Verbal Strategy Instruction on Executive Functioning

3.2.1 Complex Span Task

For the Complex Span task, a mixed ANOVA with age (4-, 6-, and 9-year-olds) and group (VSG and CG) as between-subjects factors, trial (BT and ET) as within-subjects factor, and correctly recalled trials as dependent variable revealed main effects for trial, $F(1, 111) = 185.49$, $\eta_p^2 = .63$ [BT < ET, see Figure 1 upper panel], and age, $F(2, 111) = 207.74$, $\eta_p^2 = .79$, with the Bonferroni post-hoc test revealing significant differences between all age groups [4-year-olds < 6-year-olds < 9-year-olds].The interactions between age and trial and between group and trial were also significant, $F(2, 111) = 11.40$, $\eta_p^2 = .17$, and $F(1, 111) = 4.14$, $p < .05$, $\eta_p^2 = .04$, respectively. Moreover, the three-way interaction was significant, $F(2, 111) = 3.47$, $p < .05$, $\eta_p^2 = .06$. Follow-up analyses for each age group revealed that the group x trial interaction was only significant in the 4-year-olds, $F(1, 37) = 18.45$, $\eta_p^2 = .33$, pointing to a significantly larger increase in performance between trials in the verbal-strategy group compared to the control group in this age group only (see Figure 1 upper panel).

3.2.2 Cognitive Flexibility Task

For the Cognitive Flexibility task, a mixed ANOVA with age (6-, and 9-year-olds) and group (VSG and CG) as between-subjects factors, trial (BT and ET) as within-subjects factor, and percent accuracy in switch trials as dependent variable revealed main effects for age, $F(1, 73) = 55.21$, $\eta_p^2 = .43$ [6-year-olds < 9-year-olds, see Figure 1 middle panel], for group, $F(1, 73) = 6.65$, $p < .05$, $\eta_p^2 = .08$ [VSG > CG, see Figure 1 middle panel], and for trial, $F(1, 73) = 26.89$, $\eta_p^2 = .27$ [BT < ET, see Figure 1 middle panel]. There also were significant interactions between age and trial, $F(1, 73) = 9.27$, $p < .01$, $\eta_p^2 = .11$, and between group and trial, $F(1, 73) = 19.91$, $\eta_p^2 = .21$. Most importantly, the three-way interaction was significant, $F(1, 73) = 13.52$, $\eta_p^2 = .16$. Follow-up analyses for each age group revealed that the group x trial interaction was only significant in the 6-year-olds, $F(1, 35) = 25.53$, $\eta_p^2 = .42$, pointing to a significantly more pronounced improvement between trials in the verbal-strategy group than the control group in the 6-year-olds, but not in the 9-year-olds (see Figure 1 middle panel).

3.2.3 Flanker Task

Concerning the Flanker task, trial-by-trial RTs, deviating more than 3 standard deviations from the individual's mean were regarded as outliers and excluded. A mixed ANOVA with age (4-, 6-, and 9-year-olds) and group (VSG and CG) as between-subjects factors, and trial (BT and ET) as within-subjects factor, and the interference score as dependent variable only revealed main effects for trial, $F(1, 98) = 8.26$, $p < .01$, $\eta_p^2 = .08$ [BT < ET, see Figure 1 bottom panel], and age, $F(2, 98) = 6.11$, $p < .01$,$\eta_p^2 = .11$. The Bonferroni post-hoc test for age revealed higher interference scores in both the 4-year-olds and the 6-year-olds compared to the 9-year-olds, $p < .01$ and $p < .05$, respectively. The difference between the 4- and 6-year-olds was not significant.

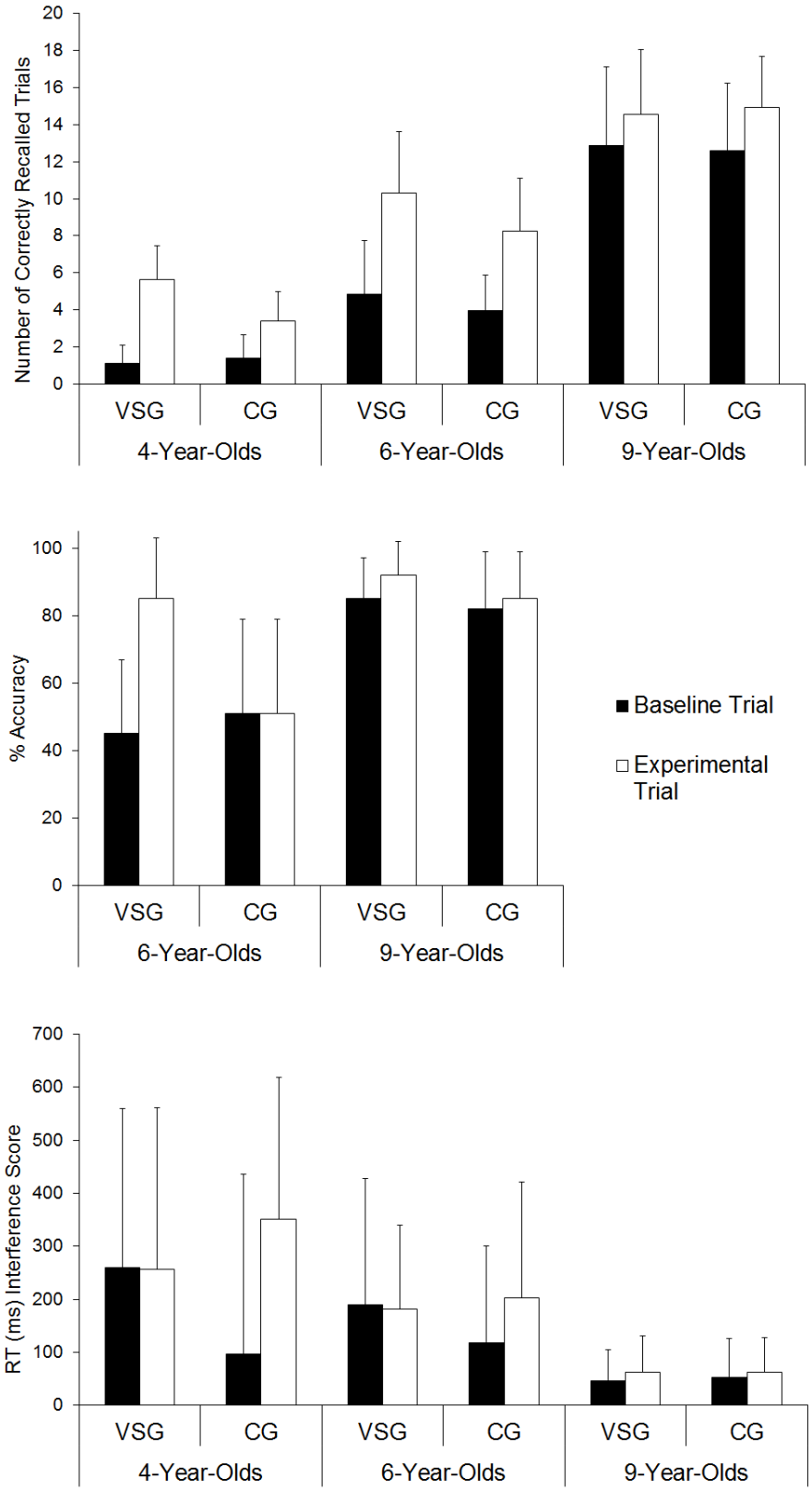

Figure 1. Performance in the Three Executive Functioning Tasks

Description: Performance in the Complex Span task (upper panel), Cognitive Flexibility task (middle panel), and Flanker task (bottom panel) as a function of age, group, and trial. Black bars represent baseline trials and white

bars represent follow-up trials in all panels. Error bars represent standard deviations. VSG = verbal-strategy group, CG = control group.

4. Discussion

By and large, the results confirmed our expectations, as the application of the verbal strategies had an enhancing effect on WM (updating) and cognitive flexibility (shifting), but not on interference control (inhibition). Furthermore, the benefit from strategy instruction was stronger the younger the children were, pointing to a general increase of verbal mediation over childhood.

Concerning WM, strategy instruction only evoked a significant enhancing effect in the four-year-olds, but unexpectedly not in the six-year-olds, although the pattern of results was very similar for these two age groups (see Figure 1, top panel). There was a pronounced performance increase between the first and the second trial also apparent in the control group. Besides practice effects, it is possible that spontaneous discovery and use of verbal strategies during the two performance trials contributed to this increase in the control group.

The effect of strategy instruction on performance in the cognitive flexibility task was unexpectedly strong in the six-year-olds, as they were able to reach the performance level of the nine-year-olds with the induced strategy. Thus, the present results do not simply counter the detrimental effect of articulatory suppression. The results rather point to the possibility that language may play a crucial role in tasks requiring the orchestration of different EF-processes. Admittedly, the cognitive flexibility task used in the present study may not reflect the most typical shifting task, but it certainly comprises demands on different EF-processes as do other shifting tasks (Best & Miller, 2010). Language's support in such multi-faceted tasks may be characterized as helping to orchestrate simultaneously operating EF-processes, an important aspect of EF-development in childhood (Best & Miller).

Concerning inhibition, labeling the target stimulus did not improve performance in the Flanker task, with this result being in contrast to Müller et al.'s (2004) findings. Besides the fact that Müller et al. tested slightly younger children, there is another crucial difference between the two studies: while the labeling of the location of the target stimulus ("middle") in the present study was not directly connected with children's response (pressing right or left), Müller et al.'s labeling of the target color was directly connected to the response (selecting the card with the respective color). Thus, language may improve inhibitory abilities only when it is directly connected to the required response and not to the task rule (see also Kray et al., 2008). The few observable spontaneous verbalizations of our four-year-olds support this assumption, as they mainly labeled the response ("left-right" or "here"). Thus, although language did not play a substantial role for inhibition, we cannot fully rule out the possibility that it supported response activation. Nevertheless, the present results in the Flanker task are in line with Vygotsky's (1934/1962) assumption of speech internalization. Based on this assumption, no need for verbal support would be expected in a task, for which inner speech was not found to be substantial in middle childhood (Fatzer and Roebers, 2012) even in younger children.

4.1 Limitations

As a limiting factor, we would like to mention that the experimental trial of our control group might not have ideally contrasted the verbal strategy inducement condition. This is because children in the control group might not have been optimally motivated to engage in the task another time with no rationale for the repetition being given. On the other hand, the question can be asked why children should benefit from the verbal strategies as they place an additional demand on children that resembles dual-tasking. In fact, this may have been a reason for the difficulties with the strategy application in the Flanker task. Nevertheless, future research may consider to induce a nonverbal strategy (e.g., pointing) as a control condition to the verbal strategy instruction.

4.2 Conclusion

Conclusively, language was confirmed to be a crucial factor for the development of EF in the present study. The effect of the verbal strategy instruction thereby countered the detrimental effects of articulatory suppression in the updating and inhibition tasks, but not in the shifting task. Thus, articulatory suppression and induced verbal strategies do not necessarily produce the same picture of language's involvement in EF. For the pedagogical context, it seems important to note that, especially when situations or tasks are multi-facetted and thus require a fine-tuned interplay and orchestration of different EF-processes, children under nine years of age may need guidance for using suitable verbal strategies to enhance performance. On the other hand, strategy instruction seems less necessary in tasks that strongly demand children's memory capacity, as it is likely that they discover and use them spontaneously.

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