Talking to Ourselves to Engage Control? Testing Developmental Relations Between Self-directed Speech, Cognitive Control and Talkativeness

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Abstract

Is self-directed speech critical to cognitive processes supporting complex, goal-directed behavior? If so, how? An influential developmental hypothesis is that children talk to themselves to support cognitive control processes, and that with age this speech becomes increasingly covert and strategic. However, while many studies suggest language supports cognitive control, evidence that self-directed speech gradually internalizes has been mixed. Moreover, extraneous factors that could co-vary with self-directed speech, age, and cognitive control, such as talkativeness, have not been systematically tested. In this cross-sectional study of 86 5- to 7-year-old children we measured overt, partially covert, inner, and strategic speech on four cognitive tasks, along with task performance and child talkativeness. We did not find consistent evidence that self-directed speech changes with age; however, we did find consistent associations between self-directed speech and talkativeness. Partially covert and strategic speech predicted performance on one task, and inner speech was implicated on another. Self-directed speech tended to correlate across tasks, and these correlations held controlling for talkativeness. Taken together, these findings suggest 5- to 7-year-old children may use different forms of self-directed speech to support cognitive control, and that the form this speech takes depends in part on factors beyond age, such as the cognitive demands of a task and child characteristics like talkativeness.

Keywords: cognitive control; executive functions; self-directed speech; language and thought

Introduction

What role does language play in our ability to flexibly override impulses and achieve goals? An influential developmental hypothesis is that language is key to the emergence and exercise of cognitive processes supporting goal-directed behavior (Luria, 1961; Vygotsky 1934/2012; Winsler, Fernyhough, & Montero, 2009). On this view, children's control processes are initially supported by the speech of others (e.g., parents and teachers), and later by children's own external speech, which is gradually internalized as inner speech (i.e., verbal thought) during childhood. Self-directed speech is thought to change qualitatively with internalization (e.g., becoming more condensed), allowing it to more effectively support cognitive control (Alderson-Day & Fernyhough, 2015; Vygotsky 1934/2012).

This hypothesis fits with a large body of research indicating that language supports cognitive control across development. Children use their own speech to support many aspects of cognitive control, including planning (Al-Namlah, Fernyhough, & Meins, 2006; Fernyhough & Fradley, 2005;), working memory (Al-Namlah et al., 2006; Flavell, Beach, & Chinsky, 1966), and task switching (Karbach & Kray, 2007). Moreover, linguistic interventions in which labels or other kinds of linguistic input are provided to children have been found to support cognitive control performance both in the moment (e.g., Kray, Eber, & Karbach, 2008) and in the longer-term (Doebel, Dickerson, Hoover, & Munakata, 2017; Doebel & Zelazo, 2016). Experiments using articulatory suppression during cognitive tasks suggest older children and adults use inner speech when engaging cognitive control (e.g., Emerson & Miyake, 2003; Kray, et al., 2008).

Key questions remain concerning the extent to which self-directed speech changes with age, and the kinds of speech children use to support cognitive control. Evidence for the hypothesis that self-directed speech gradually internalizes has been mixed. For example, while some studies have found that overt, task-relevant speech decreases with age (Winsler & Naglieri, 2003), others have not (Al-Namlah, et al., 2006; Flavell et al., 1966). And external forms of self-directed speech do not always predict performance (e.g., Doebel, et al., 2017; Winsler & Naglieri, 2003). Moreover, key variables that might account for the presence or absence of different forms of self-directed speech have not been systematically examined. For example, how talkative a child is may co-vary with age, performance, and self-directed speech, and thus could explain any relations found among these variables. Consistent with this idea, previous work has found correlations between self-directed speech and social speech/talkativeness (Al-Namlah et al., 2006; Fernyhough & Fradley, 2005).

Gaining further insight into factors that predict self-directed speech in childhood is critical both to understanding the role of language in cognitive control and how it can be improved in those who struggle with it. For example, if self-directed speech does generally internalize with age across a particular age window, this could suggest that training children to internalize their speech might help them better engage control.

The current study aimed to clarify relations between self-directed speech, age, performance, and talkativeness in children 5 to 7 years of age, a developmental period posited to reflect key transitions in self-directed speech (Gathercole, 1998; Winsler & Naglieri, 2003; Winsler et al., 2009). We assessed children's use of task-relevant overt, partially covert, inner, and strategic speech during four cognitive tasks tapping control processes. The study evaluated two contrasting hypotheses. If self-directed speech becomes more internalized and strategic with age, then age-related changes in speech should be found across tasks, and self-directed speech should be associated with cognitive performance. However, if self-directed speech does not generally change across childhood and manifests differently depending on task demands and child characteristics, then inter-task correlations among self-directed speech indices may be present, and possibly correlated with talkativeness, but relations with age should be less consistent.

Method

Participants

Eight-six 5- to 7-year-old children (M_{age} = 5.99 years SD_{age} = .61, range = 5.0 – 7.1; females = 47) were recruited from a database of families who had previously indicated interest in participating in research. Four additional children were excluded from the study due to uncooperativeness (n = 3) and developmental delay (n = 1). Some children did not complete all tasks due to failure to demonstrate understanding during practice or uncooperativeness. In total, 84, 83, 72, and 76 children completed the delayed serial recall task, selective attention task, Tower of London, and the immediate serial recall task, respectively. Most participants (> 90%) had at least one parent with a four-year college degree and were Caucasian and non-Hispanic.

Measures

Children completed four cognitive measures across two test sessions. The tasks were completed in the following order: delayed serial recall, selective attention, Tower of London, and immediate serial recall. A fixed order was used to minimize variation between subjects in task performance due to differences in order (Friedman, et al., 2008). The first three measures were used to assess external self-directed speech in addition to cognitive performance. The last measure was used to index inner speech.

Delayed Serial Recall Task (adapted from Flavell, Beach, & Chinsky, 1966; Fig. 1) Children were presented with pictures of objects serially on a computer screen, and, after an eight second delay, were asked to recall the order in which they were presented. At test, the three items were presented together in a new order, and children had to point to the pictures in the order that they saw them. Following three practice trials, children completed 10 test trials.

Selective Attention Task (adapted from Manfra & Winsler, 2006; Fig. 2) Children were shown a page of three pictures that matched on one of three dimensions (shape, color, number), and were asked to search a box for a picture card that reflected the matching dimension. The box contained 18 picture cards depicting a single dimensional value (e.g., a purple splotch or a silhouette of a star). Following three practice trials, children completed 12 test trials.

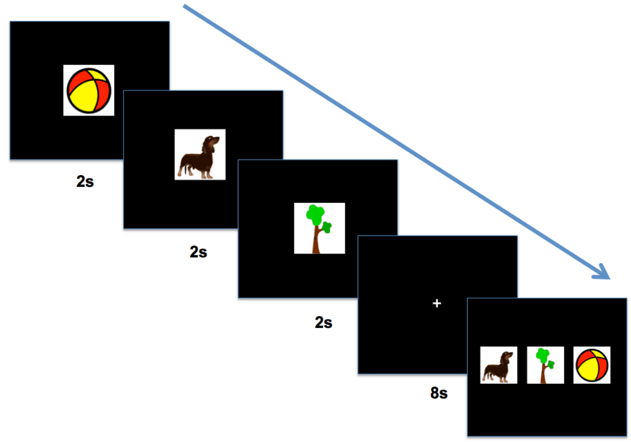

Figure 1: Delayed serial recall task.

Tower of London planning task (adapted from Fernyhough & Fradley, 2005; Fig. 3) Children were presented with two apparatuses, each of which had three wooden pegs of different lengths and three colored wooden spheres on the pegs. The spheres were configured in a different arrangement on each apparatus, and children were instructed to make one apparatus look like the other in as few moves as possible. They were also instructed that they could only move one sphere at a time and had to keep all spheres on the pegs (i.e., not holding a sphere in their hand while making moves with another sphere). Children completed six trials in total, half of which could be completed in three moves, and the other half of which could be completed in four moves. Performance was indexed by the total number of moves children made in excess of the minimum number required, divided by the total number of trials completed. If children broke rules or asked to start over, the trial was restarted. Only the final attempt at a trial and trials that were successfully completed were included in our analyses.

Immediate Serial Recall (adapted from Al-Namlah et al., 2006; Tam, Jarrold, Baddeley, & Sabatos-DeVito, 2010) This task was identical to the delayed serial recall task except that 1) there was no delay between the stimuli presentation and the test phase; 2) children were instructed not to label the pictures overtly while they were being initially presented (Al-Namlah et al., 2006); and 3) children completed two ten-trial blocks instead of one: a phonologically similar block and a phonologically dissimilar block. The phonologically dissimilar block involved the same items presented in the delayed serial recall task. The phonologically similar block involved items that had similar-sounding names (e.g., clock, clown, cat). Inner speech was indexed as the accuracy rate on the phonologically similar block subtracted from the accuracy rate on the phonologically dissimilar block, with the expectation that children who used inner speech (i.e., verbal coding of the to-be-remembered objects) would perform worse on the phonologically similar block because verbal coding would make the items more confusable.

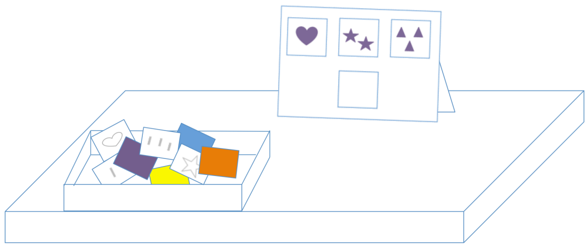

Figure 2: Selective attention task.

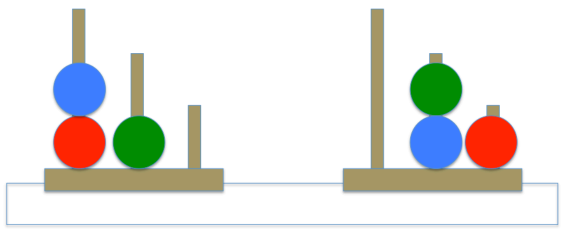

Figure 3: Tower of London planning task.

Talkativeness Parents were asked to rate their child's level of talkativeness with people he or she does not know on a 5-point scale, with 1 indicating that the child is not at all talkative, and 5 indicating that the child is very talkative. This approach was adapted from prior work in which teachers were asked to rate children's general talkativeness (Fernyhough & Fradley, 2005). We opted to ask more specifically about talkativeness with unfamiliar people in order to reduce the likelihood that parents' evaluations would reflect how talkative their child is at home, which we expected would result in a less sensitive measure.

Self-directed Speech Coding

Our coding scheme was based on prior work in this area (Winsler & Naglieri, 2003; Flavell et al., 1966). Speech during each trial of each cognitive task was coded from videos by a research assistant who was blind to the experimental hypotheses. Ten percent of the videos were coded by a second blinded research assistant and inter-rater agreement was high, *r*s > .85. Each task was coded for non-social overt speech, defined as normal volume speech not directed at another person that could support task performance (rather than meta-comments about the task or stimuli, or comments unrelated to the task) and partially covert speech, such as whispering, muttering, and lip movement.

In addition, task-specific speech strategies were coded. On the delayed serial recall task, labeling at the onset of a trial (when the stimuli were being presented) and rehearsal (during the presentation and test interval) were coded. On the selective attention task, labeling the matching dimension (e.g., "They're all purple") at the onset of or during the test trial was coded. On the Tower of London task, labeling the sphere and the location the child was placing or planning to place it was coded (e.g., "This one goes here for now"). For analyses, the number of trials on which a child used each coded form of speech was scaled by the number of trials the child completed.

Results

Self-directed Speech Variability and Frequency

As expected, all cognitive tasks elicited some self-directed speech (Table 1), and there was variability across tasks in the kinds of speech children used. However, numerous children did not use overt or partially covert self-directed speech on the tasks: 20 of 84 on the delayed serial recall task; 21 of 84 on the selective attention task; and 29 of 77 on the Tower of London task. This is comparable to rates of self-directed speech found in prior work (Fernyhough & Fradley, 2005; Flavell et al., 1966; Manfra & Winsler, 2006; Winsler & Naglieri, 2003). Children showed evidence of inner speech on the immediate recall task, performing significantly worse on the phonologically similar block ($M_{accuracy}$ = 65%, SD = 22%) than on the phonologically dissimilar block ($M_{accuracy}$ = 72%, SD = 24%), M_{diff} = .07 SD_{diff} = .17, $t(76) = 3.74$, $p < .001$, consistent with previous findings (Al-Namlah et al., 2006; Tam, et al., 2010).

Table 1: Prevalence of Different Forms of External Self-directed Speech Across Measures

Self-directed Speech Task and Index	Mean % of trials on which speech used	*N* children using speech
Delayed serial recall		
Overt speech	.30 (.42)	35
Partially covert speech	.31 (.35)	52
Rehearsal	.27 (.35)	42
Labeling	.44 (.44)	48
Selective attention		
Overt speech	.24 (.35)	38
Partially covert speech	.28 (28)	58
Labeling	.28 (.34)	47
Tower of London		
Overt speech	.16 (.27)	28
Partially covert speech	.22 (.26)	44
Labeling	.15 (.24)	28

Relations Between Self-directed Speech and Age

We found minimal support for the hypothesis that self-directed speech changes with age (Table 2). Zero-order correlations indicated that only partially covert speech on the selective attention task was related to age, such that as children got older they used less partially covert speech (Table 2). All other age/self-directed speech correlations were not significant.

Table 2: Correlations Between Self-directed Speech Indices and Age, Talkativeness, and Task Performance

Self-directed Speech Measure and Index	Age	Talkativeness	Task Score
Delayed recall			
Overt	-.17	.19^	.04
Partially covert	.13	.14	.33**
No speech	.03	-.32**	-.28*
Rehearsal	.18	.09	.31**
Labeling	-.13	.28*	.19^
Selective attention			
Overt	-.03	.32**	.01
Partially covert	-.28*	.16	-.06
No speech	.18	-.32**	.06
Labeling	-.08	.31**	.02
Tower of London			
Overt	.08	.17	.14
Partially covert	-.03	.28*	.05
No speech	.10	-.20^	-.10
Labeling	.05	.26*	-.07
Immediate recall	.00	.02	-

Note. *$p < .05$; **$p < .01$; ***$p < .001$; ^$p < .10$

These analyses were followed up with linear regressions predicting age from self-directed speech, with related speech indices simultaneously included in models to control for one another's effects, and the results were unchanged. On the selective attention task, partially covert speech remained a significant predictor, $B = -7.36$, $SE = 2.82$, $t = 2.60$, $p = .01$, whereas overt speech was not, $t < 1$, $p > .25$. On the delayed serial recall task and Tower of London, neither overt nor partially covert speech were associated with age, ts < 1.38, ps >.17. Similarly, neither rehearsal nor labeling changed with age on the delayed serial recall task, ts > 1.5, ps >.13.

Relations Between Self-directed Speech and Talkativeness

Across tasks, children who tended to use external forms of self-directed speech also tended to be more talkative (Table 2). Talkativeness was correlated with overt speech on all tasks, partially covert speech on the Tower of London (but not the delayed serial recall or selective attention tasks), and labeling (but not rehearsal) on the delayed serial recall and selective attention tasks. Inner speech on the immediate recall task was not associated with talkativeness. Talkativeness was not associated with age, $r = -.06$, $p > .25$, nor was it associated with performance on any of the tasks, rs < .16, ps > .14. As such, it was not included as a control variable in any models involving these factors.

Relations Between Self-directed Speech and Performance

Children performed well on the four tasks (Table 3) and examination of histograms did not reveal floor or ceiling effects. Self-directed speech predicted performance on the delayed serial recall task. Zero-order correlations indicate partially covert speech and rehearsal were associated with performance on the delayed serial recall task, and also indicated a marginally significant association between labeling and performance on that task (Table 2). These findings were confirmed with linear models. Partially covert speech was a significant predictor of performance on delayed serial recall, controlling for overt speech, $B = .22$, $SE = .07$, $t = 3.2$, $p = .002$, whereas overt speech was not predictive when controlling for partially covert speech, $t < 1$, $p > .25$. Similarly, rehearsal was a significant predictor of performance on the delayed serial recall task, controlling for labeling, $B = .18$, $SE = .07$, $t = 2.62$, p = .02, consistent with prior work (Flavell et al., 1966). There was also a non-significant trend such that labeling tended to predict performance on the delayed serial recall task, controlling for rehearsal, $B = .09$, $t = 1.59$, $p = .11$. However, self-directed speech on the selective attention task and Tower of London was not predictive of performance on those tasks, ts < 1, ps > .25.

Table 3: Performance on Cognitive Measures

Measure	*M*	*SD*	Range
Delayed recall	.75	.22	0 – 1
Selective attention	.94	.13	.33 – 1
Tower of London	.65	1.48	0 – 11
Immediate recall – phonologically similar block	.65	.22	0 – 1
Immediate recall – phonologically dissimilar block	.72	.24	0 – 1

Correlations Between Self-directed Speech Indices Within and Across Tasks

Many self-directed speech indices were correlated across tasks (Table 3). For example, children who used partially covert speech on the delayed serial recall task also tended to use it on the selective attention and Tower of London tasks, and children who used rehearsal on the delayed serial recall task tended to label on the selective attention task. These findings generally held when controlling for talkativeness, with the exception that some of the correlations between partially covert speech on Tower of London and other indices (partially covert speech and labeling on delayed serial recall, and labeling on selective attention) were no longer statistically significant, rs < .18, ps >.10.

We also found many correlations between self-directed speech indices within tasks. Some correlations were very strong, suggesting that certain strategies tend to be expressed more or less covertly.

Table 3: Correlations Between Self-directed Speech Indices Within and Across Cognitive Tasks

Task and Speech Index	1	2	3	4	5	6	7	8	9	10
1. DR overt										
2. DR partially covert	-.17									
3. DR rehearsal	.06	.74***								
4. DR labeling	.82***	.26*	.27*							
5. SA overt	.03	.25*	.21^	.13						
6. SA partially covert	.03	.28*	.09	.21^	.02					
7. SA labeling	.00	.33**	.24*	.19^	.87***	.30**				
8. TOL overt	-.08	.08	.00	-.08	.55***	.08	.37**			
9. TOL partially covert	.10	.20^	.16	.22^	.27*	.24*	.23*	.33**		
10. TOL labeling	-.09	.13	.09	-.03	.33*	.22^	.29*	.53**	.66**	
11. IR difference score	.06	.07	.00	.15	.16	.12	.12	.10	.04	-.09

Note. DR = Delayed recall task; SA = Selective attention task; TOL = Tower of London; IR = Immediate recall task
*$p < .05$; **$p < .01$; ***$p < .001$; ^$p < .10$.

Discussion

The current study provides several new findings related to the role of self-directed speech in developing cognitive control. We did not find evidence that self-directed speech undergoes a general internalization process with age. Instead, our findings suggest that the format of self-directed speech may depend in part on other factors like child talkativeness and the specific cognitive demands of a task. We found that 5- to 7-year-old children used inner, partially covert, and strategic speech while engaging cognitive control on different tasks, and that more overt forms of speech tended to be related to talkativeness. The finding that external forms of self-directed speech predicted performance on the delayed serial recall task but not the selective attention and Tower of London tasks suggests that children may have been supporting cognitive performance on the latter tasks with internalized speech. The delayed serial recall task likely had the highest working memory demands of all the tasks (given the need to maintain three items in mind in a particular order across time) and as such, external speech may have been necessary to support performance. Conversely, the working memory demands of the selective attention and Tower of London tasks may have been lower, and thus inner speech may have been sufficient to support performance on those tasks. For example, on the selective attention task children needed to identify a common dimension among three objects on a page and keep that dimension in mind to guide their searching, but they could always look back at the objects on the page to recall the dimension, and they only had to maintain one dimension in mind.

These findings are consistent with an alternative view of how linguistic input influences developing cognitive control, and highlight the possibility that inner speech may play a role in cognitive control from early in development. For example, teaching 5-year-old children labels that can be used to support cognitive control helps children later engage control; however, children's tendency to vocalize the labels when engaging control does not predict performance (Doebel, et al., 2017), consistent with the possibility that children can rapidly internalize speech used to support control. Foundational cognitive control processes begin to develop very early in life (Munakata, 1998), and continue to develop rapidly in early childhood, between 3 and 5 years of age (Diamond, 2013). Internalized forms of self-directed speech could be critical to the emergence of these processes.

An alternative interpretation of our findings is that there are indeed robust age-related changes in self-directed speech, but that our age range and sample size were too constrained to detect them. For example, prior work has found age differences in the use of rehearsal to support serial recall when the age groups being compared were 5, 7 and 10 years (Flavell et al., 1966), and that overt self-directed speech decreases with age in a large sample aged 5 to 17 years (Winsler & Naglieri, 2003). However, given the frequency and variability in speech use in the current study, and that our sample spanned an age range identified as a transition period in the use of self-directed speech (e.g., Winsler & Naglieri, 2003; Winsler, et al., 2009), it was surprising that age was not a significant predictor of speech on most tasks. Another possibility is that age-related patterns only manifest when cognitive demands are high and inner speech is insufficient to maintain the goal representations guiding performance. Future experiments can test this by manipulating the maintenance demands in a task and testing associations between age and self-directed speech.

Our findings are correlational, leaving open alternative explanations for the relation between self-directed speech and cognitive control. For example, it is possible that developmental increases in cognitive control lead to changes in self-directed speech (and that self-directed speech is epiphenomenal). Or a third, unmeasured variable may explain the relation between self-directed speech and cognitive control. Experiments manipulating cognitive control and testing influences on self-directed speech, and vice versa, could address this causal issue.

Self-directed speech may be a good target for interventions to improve cognitive control. Given that cognitive control develops dramatically in early childhood and predicts success in life across a range of outcomes (e.g., academics, health, and wealth; Moffitt, et al., 2011), there has been great interest in developing effective interventions to improve it. However, results of interventions to date have been mixed (e.g., Melby-Lervag & Hulme, 2013). One potential reason is that approaches to date have not optimally targeted the processes that support developing cognitive control. Training children to use different forms of self-directed speech to support cognitive performance, such as labeling, rehearsal, and partially covert speech, may be a fruitful approach to improving control in children.[1]

The current study advances knowledge on the role of self-directed speech in cognitive control by suggesting that the kinds of speech children use to support cognitive performance in childhood may depend on a range of factors beyond age, such as child talkativeness and the cognitive demands of a task. Future work can further test how self-directed speech relates to cognitive control and how it can be targeted in cognitive control interventions.

Acknowledgments

This research was supported by the Eunice Kennedy Shriver National Institute of Child Health & Human Development of the National Institutes of Health under Award F32HD079191.

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[1] Children have been successfully trained to use rehearsal to support delayed serial recall, but they stopped using the strategy when told they did not have to use it (Keeney, Canizzo, & Flavell, 1967). Whether children stopped because they could not sustain the strategy or because the experimenter's instructions influenced motivation to use it is not clear.

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