Developmental Transitions in Private Speech

Implications for Real World Executive Function

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Abstract

The use of private speech (PS), non-social speech that is audible or internalized, is important for engaging in the successful use of executive functions (EFs). EFs are general mechanisms that allow us to control and regulate our behaviors, thoughts and feelings. A developmental transition has been posited in private speech during early childhood, changing from overt to more covert with age; this transition might support developmental improvements in EFs. However, previous research has focused on a limited set of tasks, has not tested whether overt private speech might decrease with age due to other factors (e.g., talkativeness), and has not tested how private speech relates to real-world EF. The current study investigated the developmental transition in private speech in a cross-sectional sample of 30 children between the ages of 5 and 7 years old. The use of four cognitive tasks allowed a test of the generalizability of developmental changes in private speech. Correlations were found across a few tasks but not across the entire battery, which may suggest that children utilize different levels of PS based on task demands. Two covariate measures (talkativeness and extroversion) allowed a test of whether other factors may play a role in overt private speech. Extroversion was significantly positively correlated with some tasks, and negatively correlated with age, which suggests that developmental decreases in overt speech may be driven by developmental decreases in extroversion. Real-world EF was assessed via a parent questionnaire, the Behavior Rating Inventory of Executive Function (BRIEF). Use of PS on some tasks was trending with BRIEF scores, which suggests that PS may play a role in real world EF. While promising, issues of small sample size, floor effects in private speech, and challenges of coding private speech highlight the need for further research to determine the time course, universality, and influence of PS on the development of EF.

Keywords: Private Speech, Executive Function, Developmental transition, Cognitive Development

Introduction

Executive Functions (EFs), are general mechanisms that control and regulate cognition and behaviors such as problem solving, inhibition, and self-regulation, and are important for the performance of many everyday tasks (Miyake, Friedman, Emerson, Witzki, Howerter, & Wager 2000). Additionally, EFs may be important for positive later life outcomes, translating into achievement at both work and school (Moffitt, Arseneault, Belsky, Dickson, Hancox, Harrington, & Caspi 2011). Thus, due to the importance of EF throughout development, it is important to gain insight into what mechanisms underlie its development and effective use.

Private speech (PS) may play a key role in the development of EFs. PS is non-social speech that may be audible or internalized and may be used to support controlled behavior (Vygotsky 1934/1986). Vygotsky's theory supposes that speech first arises to serve social, communicative functions, but that this speech may also function as a tool that helps scaffold higher levels of thinking (Vygotsky 1934/1986). Individuals may use PS in order to more readily engage EFs. For example, when completing a jigsaw puzzle an individual may use PS to assist in guiding the progression of the task saying "this is a corner piece, so I'll set it over here for now," or "need a piece with blue on half." There are a variety of ways one may engage in PS, talking to oneself out loud, whispering, or mumbling, and the use of this speech is seen commonly amongst the early elementary school population. Additionally, PS has been found to play an important role in the mature use of EFs, as demonstrated through studies with adults (Emerson & Miyake 2003). For example, interfering with PS through speech-based dual-task

manipulations disrupts EF more than alternative dual-task manipulations that do not interfere with PS.

Vygotsky's theory proposes a transition from overt (audible) to covert (internalized) private speech through development. A large body of research has supported Vygotsky's proposed transition and notes a general transition period between the ages of 4 and 8 years (e.g., Al-Namlah et al. 2006; Fernyhough & Fraley 2005; Frauenglass & Diaz 1985; Bivens & Berk 1990). Research conducted on children's use of PS while engaged in classroom tasks found a transition from more audible forms of PS to more partially covert methods such as whispering, or lip movements, between first and third grade (Bivens & Berk 1990). A report of four PS studies furthered support for this developmental transition, assessing PS in both naturalistic and task-related contexts, finding higher incidents of PS among 4- to 6-year-olds with a decline into more covert forms and in some cases of older children, was completely absent, presumably given their capabilities of internalized thought (Kohlberg, Yaeger, & Hjertholm 1968).

Extant empirical findings are thus consistent with the possibility that a key developmental transition in private speech exists and may be used to guide EFs; however, more research is needed to test this progression, using multiple indices of PS on a range of cognitive tasks. A majority of the literature has tested the transition using only one or two tasks (Fernyhough & Fraley 2005; Lindstone, Meines, and Fernyhough 2011; Winsler, Diaz, and Montero 1997; Winsler & Naglieri 2003). In cases where two tasks were used they frequently measured the same cognitive domain. For example, one study measured PS on delayed and immediate recall memory tasks (Flavell, Beach, and Chinsky 1966). Other studies looking at two differing tasks have reported similar transitions in PS across tasks; this is an improvement over a single task or two similar tasks, but it is still difficult to distinguish whether a general transition in PS is being

measured, or if the changes seen in speech relate to the tasks specifically. For example, some tasks may be selected based on their ability to elicit PS, which then increases this difficulty. Combining across multiple tasks may allow for a robust index that provides a better estimate of an individual child's level of PS.

Prior research has not controlled for variables that could account for patterns in the proposed transition, such as talkativeness and extroversion. For example, children might be less talkative with age, which could account for overall reductions in overt and partially covert PS. Additionally, more extroverted individuals may be more comfortable talking to themselves in front of an experimenter, which could influence levels of PS production. Measuring these variables may thus establish whether a child's amount of overt speech is the result of their position in the transition or if these external factors may encourage speech on a task. Furthermore, after controlling for such covariates one could potentially investigate how this developmental transition might relate to other developmental constructs including EF.

Extant research has measured PS in the context of lab tasks that require use of EFs, but there has been no investigation of how PS might be related to real-world EF. Examples of EF in the real world include inhibiting compulsive, inappropriate behaviors while in public, or multitasking at work or school. Given the everyday applications of EF that allow us to adapt to changing circumstances, it is important to understand how other developmental transitions may be influencing EF development. Furthermore, if private speech becomes more internalized with age as is proposed in the transition, then this might relate to real world EF.

The current study attempted to address these questions by measuring PS on a wide range of cognitive tasks, including a task-switching paradigm, to see if speech tracked across different modalities. Task-switching was used as a canonical EF measure and was not selected based on

the expectation it would elicit speech, unlike tasks used in previous research. Using tasks known to elicit speech inherently complicates the ability to determine whether a general developmental transition exists or if only targeted tasks elicit observed effects. Additionally, measures of talkativeness and extroversion were included as covariates to assess whether the purported relationship between PS and age holds when accounting for these individual differences. If the developmental transition in PS is seen across tasks and when controlling for talkativeness, then this suggests a stronger argument for the presence of the transition. Furthermore, the current study also utilized a measure of real world EF to test whether a relationship exists between PS and EFs.

Methods

Participants

Thirty school-age children between the ages of 5 and 7 years (range 60.4 to 85.2 months) were tested. Two additional children were excluded due to failure to cooperate with the experimenter. Children were recruited to the study through a database with families who had previously indicated interest in participating in developmental research. Ninety-four percent of children in the sample identified their ethnicity as non-Hispanic; the remaining six percent identified as Hispanic or Latino. Eighty-seven percent of participants identified their race as white, ten percent as more than one race, and three percent (one child) as American Indian. The distribution of racial and ethnicity classification closely matched that of the local community from which the sample was selected (Boulder, CO). Families were compensated five dollars for each visit to help with any travel cost.

Procedure

Children were tested and video-recorded individually over the course of two, one-hour sessions, spaced approximately one week apart (plus or minus 3 days). Four primary cognitive tasks were administered to assess children's task-related private speech: a computerized task-switching paradigm, the Selective Attention task, Tower of London (TOL), and Delayed Recall task. In addition, talkativeness and extroversion were measured using questionnaires. Tasks were administered in the following order: Session 1: delayed recall, task-switching, and the Selective Attention task; Session 2: TOL. These tasks were a subset of a larger battery of tasks administered in a study investigating transitions in private speech and proactive control. To minimize additional sources of variation in PS, children were tested by the same experimenter across the two sessions.

Primary Cognitive Tasks

Private speech was measured across several tasks that exercised a range of cognitive skills (memory, switching, selective attention, planning). The procedure for transcribing and coding private speech is described in detail below.

Delayed Recall (adapted from Flavell, Beach, and Chinsky 1966). In this task children had to recall three pictures in the order they were initially presented on a computer screen. Children were initially presented with all picture stimuli and asked to name the object pictured in each, to ensure understanding. Following picture naming, the experimenter pointed to a set of three pictures in a specific order and requested that the child point to the same order in which the pictures were pointed to. This was repeated a total of two times. A series of three practice trials were then introduced, on each trial, children were shown three pictures presented one at a time on the screen, followed by a delay period of approximately 10 seconds, after which all three images reappeared on the screen in a rearranged order (see Figure 1). Children were asked to

point to the pictures in the order in which they remembered seeing them. Children's responses were keyed into the computer by the experimenter. If the child did not accurately complete each practice trial, the demo was reinitiated and children were taken through the practice trials once more. Following completion of the practice trials children completed a total of 10 test trials.

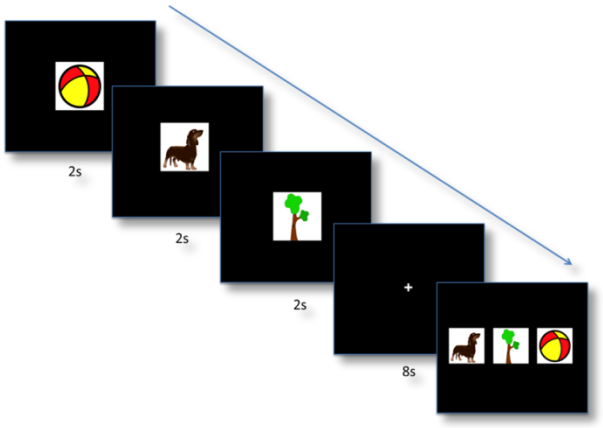

Figure1. Schematic of Delayed Recall task. On each trail children were presented with three pictures one at a time, followed by a 10 second delay period. Following the delay period all three picture reappeared on the screen in random order.

Task-Switching (Chevalier, Martis, Curran, & Munakata 2015). In this computerized task, children were asked to sort a series of toys for Santa. Children were instructed to attend to a task cue that indicated one of two tasks they needed to complete: sorting a target object (toy) by shape (bear or car) or by color (red or blue). The task to be performed alternated pseudo-randomly across trials. Children's responses were recorded using a button box linked to the game; buttons were each labeled with one of the four possible options, blue dot, red dot, bear, or car. The task cue was a black circle filled with color splotches (indicating the color game) or shapes (indicating the shape game) and was presented in advance of the target's appearance and remained on the screen after the toy appeared (Figure 2). Children completed a demonstration phase in which the experimenter explained the rules and gave children the opportunity to try each task. If a child failed to correctly sort all of the toys during the practice trials, the experimenter would reiterate the importance of attending to the circle around the toy "remember

to look at the circle so you know which game to play," and would restart the practice trials. Following the demonstration phase, children independently completed a total of 30 test trials.

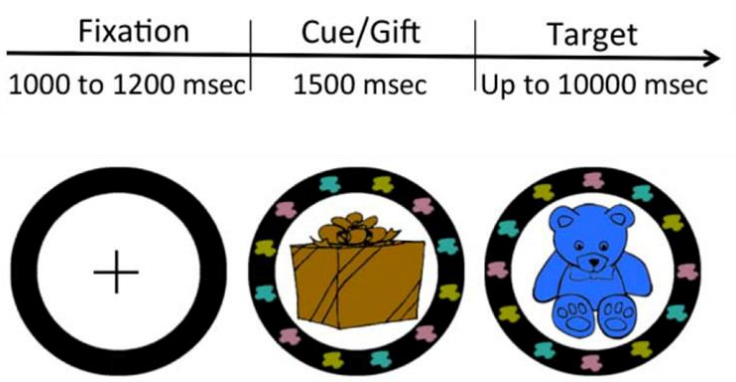

Figure 2. Diagram of task-switching paradigm. Color splotches in the circle surrounding the present represent the cue to sort the target (toy) by color. (Chevalier et al. 2015)

Selective Attention Task (Winsler, Diaz, and Montero 1997). Children were shown a set of three pictures that all matched on one dimension: color, shape, or number, and were instructed to find a picture card in the adjacent box that matched the three original pictures. The box of pictures for matching contained a total of 20 options, each depicted a single dimension (e.g., a silhouette of a heart, three grey rectangles, or the color yellow), and only one card in the box was a perfect match for what was presented on the page, some cards were decoys. Children were presented with a demo trial and asked how the three pictures in front of them matched and were instructed to find the picture card that related to the pictures on the board. After selecting the matching picture, children were instructed to attach the picture card to a space on the board outfitted with Velcro (Figure 3). If children were unsuccessful in obtaining the correct answer on the demo and two subsequent test trials, the experimenter explained the answers and assisted the child in looking for the matching picture in the box. In addition to attaching the pictures to the board, children were instructed by the experimenter to remove the picture card, placing it back in the box, and were shown how to flip the page on the board in order to being the next trial.

Following the practice trials, the experimenter excused themselves to the back of the room to allow the child to complete the game on their own. Children completed a total of 12 test trials.

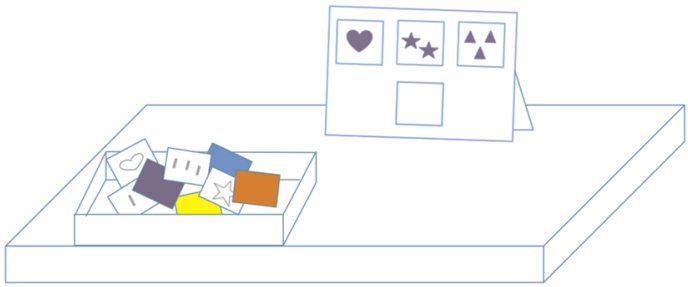

Figure 3. Diagram of selective attention layout. Children selected picture cards from the box and matched them to a set of three pictures presented on a board.

Tower of London (Fernyhough & Fraley, 2005). This planning task required children to configure an apparatus to match a model in as few moves as possible. The apparatus consisted of two wooden blocks with three pegs of differing heights on each, along with three colored balls that contained holes to rest on the pegs (Figure 4). During the task the experimenter presented the child with a specific configuration of the puzzle on one of the apparatuses. The child was instructed to move balls around on the remaining apparatus so that the arrangement would look the same as the model. To ensure that children would have to plan in order to make the two apparatuses match in as few moves as possible, children were required to adhere to specific rules: only one ball could be moved at a time, balls were to be kept on the pegs (could not be placed on the table), and only one hand could be used to play. In total children completed 8 trials including 2 practice puzzles requiring 2 moves and 6 test trials (3 trials requiring a minimum of 3 moves to solution and 3 trials requiring 4 moves).

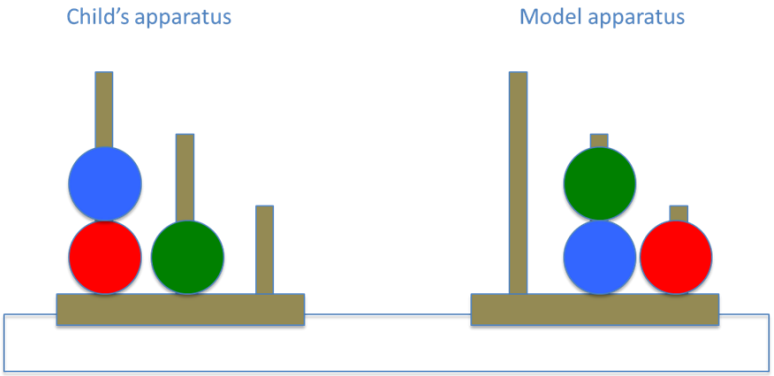

Figure 4. Schematic of TOL apparatus. Children were required to colored balls on their apparatus in order to make it look the same as the model.

Covariate Measures

Talkativeness. This study included a measure of talkativeness as assessed by a brief parent questionnaire. Overall levels of talkativeness for each child were determined based on 3 questions: how talkative is your child at home (with family), how talkative is s/he with strangers, how talkative is s/he when working on something alone. Parents responded to each question using a 5-point Likert scale ranging from "not at all" to "very". Talkativeness was measured with one question, the question about talkativeness with strangers.

Extroversion. Extroversion was assessed by the Child Behavior Questionnaire (CBQ), which was completed by parents during the first session. Scores for extroversion were determined based on mean scores of a subset of questions on the Surgency scale; these scores were then used as a covariate across tasks.

Private Speech Transcription and Coding.

Transcription

Children's private speech during the cognitive tasks was transcribed from videos. Following Winsler (Winsler, Fernyhough, McClaren, & Way 2005): Utterances were defined as patterns of speech that were separated by a minimum of two seconds and included a variety of structures such as: sentence fragments, complete sentences, a clause with a distinguishable end point, or a change in subject. Additionally, utterances could not have any signs of discontinuity in content or spacing, and if speech was inaudible, any segment of that speech that was not separated by the minimum two second break, was also classified as an utterance. Utterances were transcribed verbatim where possible, and it was indicated whether the utterance was expressed as a whisper or lip movement, or full volume but not decipherable. Transcribed utterances were

then classified as social or private. Utterances were classified as social if the child showed extended eye contact with another person in the room during the utterance or within two seconds of its completion, the child involved another person through physical contact, the utterance had the same subject or was a question pertaining to a person's prior social utterance, or if the utterance occurred less than two-seconds after another social utterance. Any utterance not meeting these conditions or guidelines was classified as private speech.

Coding

The coding protocol was established to determine the absolute frequency of overt and partially covert private speech on a given task. All PS utterances that occurred during a task were coded however, despite the transcription of utterances classified as social speech, only the frequency of PS utterances were coded. Private speech utterances were classified as 1) overt (audible, full volume); 2) partially covert (low volume, whisper, or lip movement (Flavell, et al., 1966; Winsler & Naglieri, 2003). Frequency of utterances was determined using the same guidelines listed in the transcription section that define individual utterances.

Results

Relationships among PS measures

There did not appear to be any clear correlations between the amounts of private speech across tasks, within overt or covert PS. PS was not found to significantly correlate across tasks; however the data were not normally distributed across the age range or for private speech utterances, which limits what conclusions can be drawn about the relationship between tasks. Despite this, a large amount of variability was seen for overt utterances on the Selective Attention task, and partially covert utterances on Delayed Recall (see Figure 5). Linear regressions tested whether frequency of PS was correlated across tasks. Figures 6 and 7 show

plots for the relationship of partially covert and overt PS utterances across tasks respectively, suggesting that partially covert utterances appeared to correlate between the Selective Attention task and Task-switching paradigm r(30) = .38, p = .038, and between TOL and Task-switching r(28) = .78, p < .001 (see Table 1). Although correlations among these tasks appeared to be significant, they could ultimately have been driven by a few outliers in the sample. Overt speech showed similar patterns across some tasks with positive, trending correlations between Selective Attention and Task-switching r(30) = .32, p = .084, and TOL and Selective Attention r(28) = .56, p = .0019 (see Table 2). Again, these results might have been influenced by some key points and the non-normal distribution of the data.

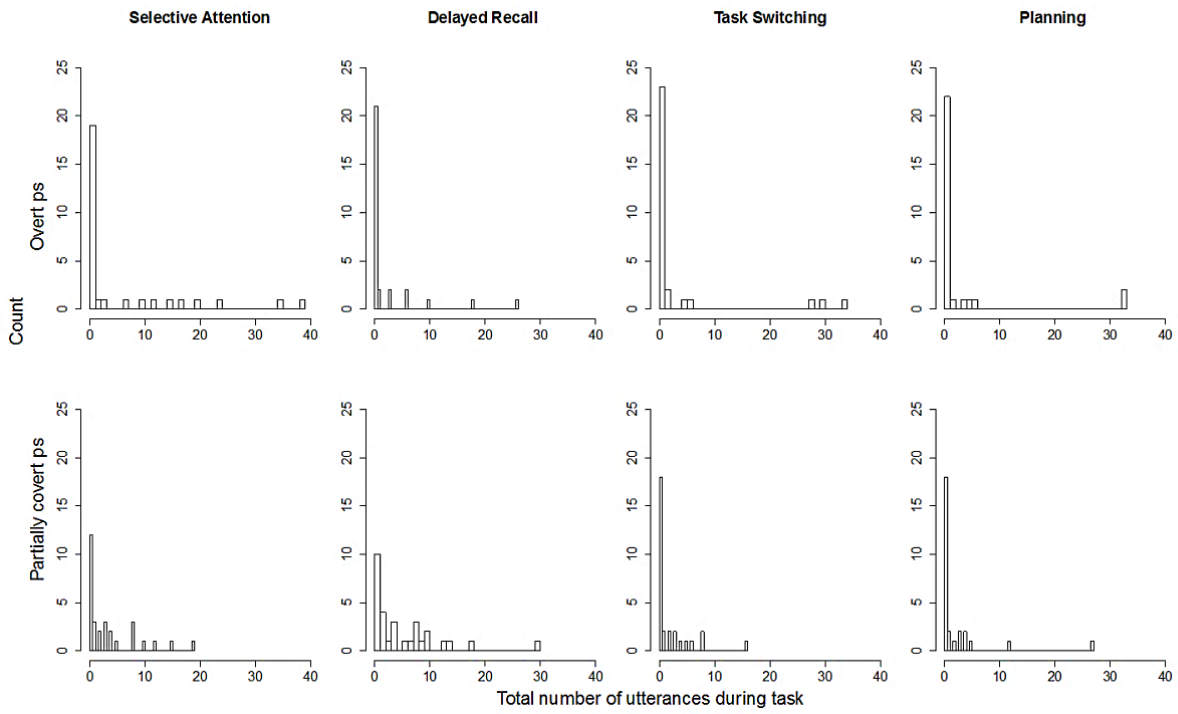

Figure 5. Frequency of private speech across tasks. The total number of partially covert and overt utterances are measured separately for each task, along with the number of participants who completed that

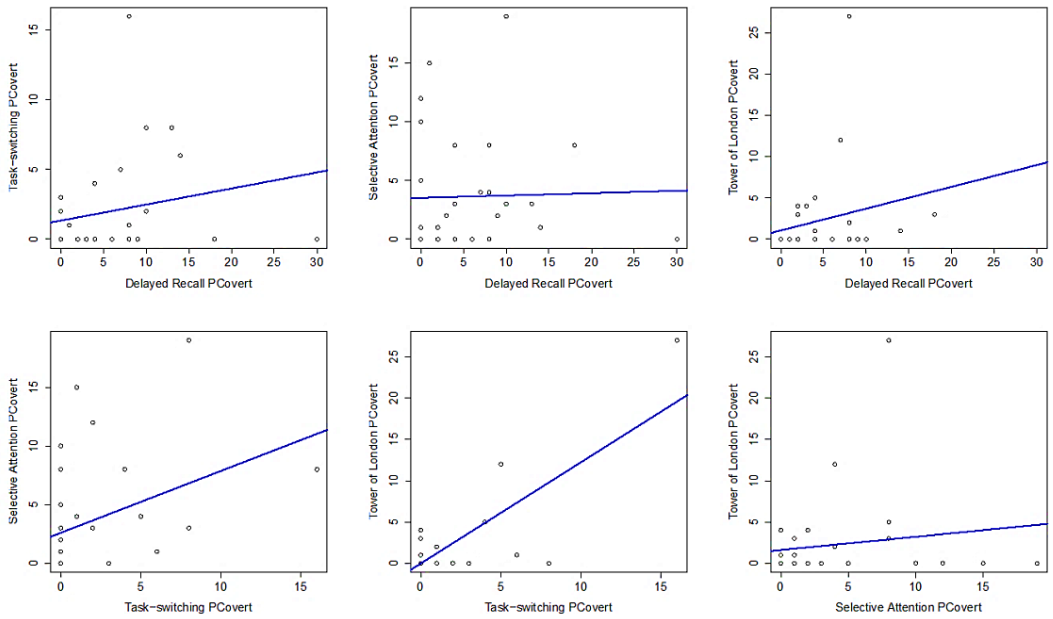

Figure 6. Relationship of partially covert speech between tasks. Each plot displays the number of partially covert utterances produced on each task in relation to each of the other tasks.

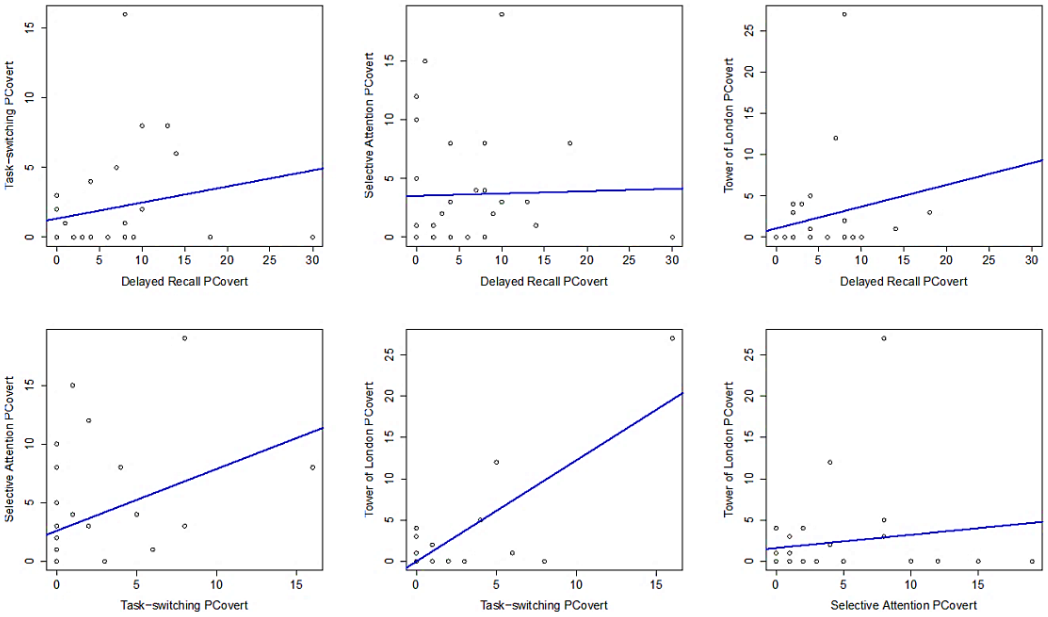

Figure 7. Relationship of overt speech between tasks. Each plot displays the number of overt utterances produced on each task in relation to each of the other tasks.

Table 1. Task Correlations Partially Covert.

Measure	1	2	3
1. Delayed Recall	-	-	-
2. Task-switching	.22	-	-
3. Selective Attention	.03	.38*	-
4. Tower of London	.23	.78**	.15

Table 2. Task Correlations Overt.

Measure	1	2	3
1. Delayed Recall	-	-	-
2. Task-switching	.19	-	-
3. Selective Attention	-.02	.32^	-
4. Tower of London	.01	-.07	.56**

Relationships among PS, age, and covariates

The prevalence of partially covert speech on the Selective Attention task was significantly negatively correlated with age $r(25) = -.414$, $p = .02$, while partially covert utterances were positively correlated with age on Delayed Recall $r(22) = .42$, $p = .028$. However, when controlling for talkativeness and extroversion the correlations weakened: Selective Attention: $r(25) = -.39$, $p = .049$, $r(25) = -.31$, $p = .11$, Delayed Recall: $r(22) = .37$, $p = .06$, $r(22) = .31$, $p = .10$. Additionally, when overt utterances were compared to levels of talkativeness and extroversion, some positive correlations were seen across tasks (see Table 3). Talkativeness and extroversion showed significant positive correlations with overt utterances for Task-switching and Selective Attention. Additionally, extroversion was found to decrease with age $r(25) = -.34$, $p = .06$, while talkativeness was not found to correlate with age.

		Talkativeness	Extroversion
Overt	Age	.00	-.34^
	Delayed Recall	-.08	.17
	Task-switching	.42*	.51**
	Selective Attention	.41*	.45*
	Tower of London	.13	.07
Partially Covert	Delayed Recall	.23	.22
	Task-switching	.10	.05
	Selective Attention	.06	.23
	Tower of London	-.04	-.05

Table 3. Association of talkativeness and extroversion across tasks.

Relationships between PS and EF

Real-world executive function was associated with one out of eight private speech measures (4 tasks, with overt and covert PS measures on each task). A correlation analysis showed a significant negative relationship between BRIEF scores and partially covert utterances on the Selective Attention task ($p < .05$, see Table 4). In addition, this result held when controlling for age $r(25) = -.46$, $p = .02$ (see Figure 8). Though none of the other measures significantly correlated with the BRIEF, five of the remaining seven categories showed mild negative correlations including partially covert utterances on Delayed Recall and Task-switching, as well as overt utterances on Task-switching, Selective Attention, and TOL.

Task	BRIEF
Delayed Recall Overt	.16
Delayed Recall pCovert	-.15
Task-switching Overt	-.14
Task-switching pCovert	-.20
Selective Attention Overt	-.20
Selective Attention pCovert	-.46*
Tower of London Overt	-.19
Tower of London pCovert	.07

Table 4. Private speech correlations with BRIEF scores across tasks.

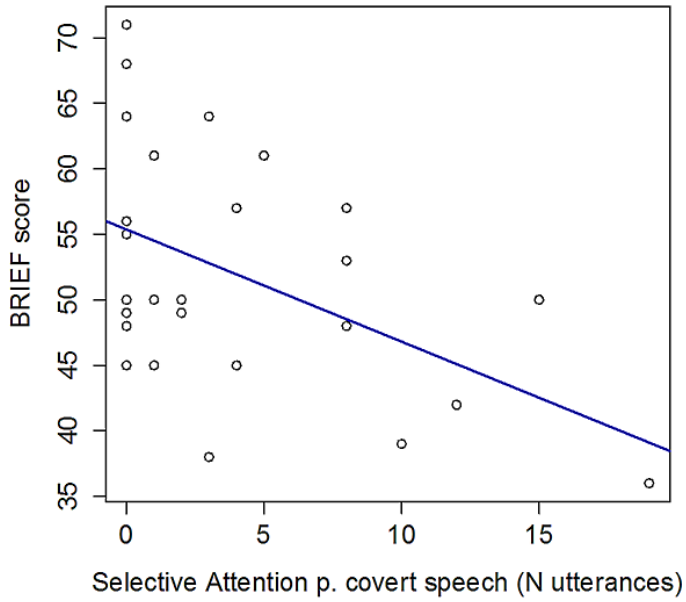

Figure 8. Relationship between partially covert speech on Selective Attention task and BRIEF scores when controlling for age.

Discussion

Previous work shows support for a developmental transition of private speech from overt to covert; our study attempted to assess the transition across age through a series of cognitive tasks. Specifically, there was some support that partially covert speech transitions with age as seen in the Selective Attention and Delayed Recall tasks. These results are consistent with the notion that PS changes with age, because an increase in partially covert speech with age signifies the next step before the emergence of entirely covert PS. However, results of this study suggest that the transition may not present itself the same way or occur simultaneously across all tasks, given that only a few instances of PS on tasks correlated between two tasks. Overall, the tasks used here and in the literature may vary in the amount or type of PS that is needed to support performance, since there was considerable variation in PS across all tasks and ages.

The positive correlations of overt speech with talkativeness and extroversion on some tasks supports the idea that external factors may explain the apparent developmental transition in private speech. Since extroversion was shown to decrease with age and given its relationship to overt speech on some tasks, this suggests that a decrease in extroversion with age may mediate declines in overt utterances during the same period. Thus, changing levels of extroversion could be responsible for the appearance of the transition from overt to covert, but more data is needed to confirm this. While talkativeness was correlated with some tasks, its lack of a correlation with age makes it difficult to say if it is influencing the transition.

While real-world executive function does not appear to correlate with private speech on most tasks, the results suggest that EF may play a bigger role in some tasks than others. It is possible that we see the negative correlation of partially covert utterances on the Selective Attention task and the BRIEF because this task may be a more sensitive measure of EF, while other tasks may have failed to reach significance with the BRIEF because children appeared to use greater amounts of covert PS, with less variance in the distribution. The verbal mediation required to complete the Selective Attention task successfully may involve higher level cognitive processes compared to that of other tasks. Children completing the task are responsible for synthesizing multiple pieces of information, assessing how three pictures relate to each other and subsequently keeping that information in mind while also looking for the matching piece. While other tasks may require use of EFs the demand may ultimately not be as high. For example, on Delayed Recall, partially covert and overt utterances simply involved the labeling or repetition of the picture order, while SA elicited greater amounts of higher level utterances. Thus, if the account of previous work holds that partially covert speech decreases with age as children develop greater amounts of covert, internalized thought, then this is paralleled with ideas of EF

increasing with age. As children develop greater mastery of EFs, we should in theory see less reliance on overt and partially covert speech when completing a task, because they may no longer need this to scaffold performance on some tasks. Furthermore, if the correlation between the change in PS on Selective Attention and the BRIEF is a reliable finding, this extends previous research by showcasing how PS might predict EF outside of the lab context.

Limitations and Future Directions

This study disproportionately sampled children in the upper fourth of the desired age range (60-84 months), with most participants ranging between 78-84 months of age, which may have contributed to the limited picture of the developmental transition. As exhibited in many of the plots, a large number of children were at floor for private speech production across multiple, and in some cases, all tasks. Due to the difficulty in interpreting the absence of speech, which could be internalized thought or nothing at all, it is hard to determine how this information may or may not play a role in the purported transition, although this limitation is encountered by much of the extant research on this topic. It is possible that the upper end of the age range was further along in the transition and thus was not as likely to exhibit overt and partially covert forms of PS, while a limited number of participants in the lower age range may have resulted in smaller amount of variability across PS production, thus minimizing the scope and shape of the developmental transition. Future research should address this by sampling more evenly across the age range and potentially widening the age range to characterize if the transition is focused in a subset of the age range. By gathering a more evenly distributed sample we may be able to account for the overall transition and gain a clearer insight into the possible relationships between tasks, their relation to age, and applicability to real world EF.

Future research may clarify if the developmental transition is something seen broadly across tasks and related to the individual's development, or is something seen within individual tasks that may be induced by task difficulty or EF demands. It is possible based on our current findings, the transition seen within tasks, not across all tasks, that children may experience their own individualized form of the transition, and additionally may not necessarily follow the path established in previous work. Thus, some children may follow the pattern of overt to covert, while some children may never experience a use of overt PS, instead transitioning from partially covert to covert. Still others may never lose the overt utterances while engaged in problem solving. The current study was not able to address this because of the limited dataset, but future research should continue to address these issues as it contrasts ideas about the transition in the literature. To accomplish this, future research should attempt to look at these transitions using a longitudinal design that would allow the researchers to track changes in individual children across development.

Though controlling for talkativeness and extroversion were important in attempting to determine their relationship to transitions in private speech, the measure used for talkativeness was likely not as sensitive and the measure of extroversion. Using the same measures of extroversion may work well however, future research should attempt to develop a more sensitive way of assessing an individual's talkativeness. Utilizing these covariates once more in a future sample with a larger age range could further test whether any relationship between age and PS is explained by talkativeness or extroversion. With a larger sample the data could possibly show that these variables are not just items we should control for, but may be components that help children use speech in the service of EFs.

Furthermore, although sensitive measurement of the relationship between PS and real world EF was only found on one task, future work can expand on this given the findings on Selective Attention and the general levels of EF that are required to complete the other tasks. Additionally, the relationship between PS and EF may have been diminished due to the measure of EF used. Only the parent form of the BRIEF was filled out for each participant, which may inherently result in biased answers from parents. Future research should utilize the full BRIEF including both the parent and teacher forms, which when combined could provide a more sensitive measure of children's real world EF.

Conclusion

Despite the small sample with which this study attempted to assess the developmental transition of private speech, it produced important findings that lay the ground work for future investigation. Though the shape of the transition is not confirmed across all tasks, the potential relationship between developing PS and EFs is an exciting piece that may eventually inform our understanding of development across both domains. Ultimately, findings on this topic could have broad reaching impacts due to the desire for greater levels of executive functioning throughout our lifetime.

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