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# Executive Function Predictors of Children's Talk

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ABSTRACT

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Relatively few studies have investigated the relationship between executive functioning (EF) and language development, and even fewer have researched hot and cool EF as a predictor language development. The proposed study is an investigation of the relationship between EF and language development in preschool aged children. More specifically, the ability for hot or cool EF to predict language, this will be the focus of the study. It is expected that cool EF will be a better predictor of language development in preschool aged children.

## Introduction

In recent years, executive functioning (EF) has become the topic of empirical research in young children. In this literature, researchers typically focus on three major components of EF: attention allocation, short-term memory, and inhibition of behavior. As a result of the collaboration of these subcomponents, EF allows children to maintain task-relevant information in their short-term memories to utilize for future behaviors and actions, and to inhibit actions that may be immediately desirable but otherwise counter-productive toward achieving short and long-term goals. Thus, well-developed EF systems promote successful functioning in domains ranging from social development to school readiness (Bull & Scerif, 2001; Mischel, Shoda & Rodriguez, 1989). Recently, researchers have become interested in two subtypes of EF: hot and cool. Hot and cool EF, which are described in detail below, are shown to independently predict certain outcomes. Hot EF, for example, has been found to predict inhibition of behavior and attention, (Brock, Rimm-Kaufman, Nathanson & Grimm, 2009), while cool EF predicts allocation of attentional processes (Carlson &Wang 2007).

## Executive Functioning Overview

One of the reasons that researchers have become interested in studying EF in early childhood is because it has been found to be predictive of later childhood performance in a number of different domains. For example, early EF has been found to promote social development (Moriguchi, 2014). EF may be relevant for children's social development because of the potential role it plays in children's understanding of their peers' mental states. In particular, Carlson, Mandel and Williams (2004) suggest that EF promotes mental state reasoning. Consider the role of EF in one popular way to measure children's understanding of mental states, the false belief task (or the Sally Ann Task) (Zelazo, M., Zelazo, P., & Imrisek, S. (2005).

The Sally Ann task involves children being introduced to two dolls and shown that in front of the dolls is a basket and a box. The children are then shown that one of the characters, Sally, places her marble in the basket, and then leaves the room. The other character, Ann, then moves the marble into a box. When Sally returns, the researcher asks the child "where would Sally think the marble is?" Although this task was developed to test a child's theory of mind, Carlson et al. (2004) suggest that this task also requires EF, because children must inhibit their initial responses and think before responding. For example, children must inhibit their desire to point to the actual location of the object and identify instead the expected location of the object from Sally's point of view.

EF has also been linked to school readiness (Stelzer, Mazzoni & Cervigni, 2014). Researchers have focused particularly on how EF predicts success in specific subject matter topics. To this end, for example, higher scores in EF during preschool have been found to predict quantitative scores on the Scholastic Aptitude Test in children's senior year of high school (Metcalfe & Mischel, 1999). EF has also been shown to predict children's vocabulary performance. For example, Mischel, Shoda, and Rodriguez (1989) have reported a correlation between EF and the vocabulary section of the SAT.

Just as EF promotes success in social development and school readiness, impairments of EF result in the impairments of social judgment and academic performance (Carlson, Mandell & Williams, 2004). Van der Sluis, de Jong, and Van der Leij (2006), for example, report that deficits in EF have been linked to learning disabilities and attentional problems.

In sum, links between EF and social and academic readiness have been well established. However, EF has been associated with a number of additional developmental outcomes, including self-regulation (Bernier, Carlson & Whipple 2010), emotional regulation (Zelazo, Cunningham & Gross 2007), and predispositions to behavior disorders (Barkley, 1997). Given the wholesale linkages researchers have found between EF and various development outcomes, recent focus has been placed on subtypes of EF, particularly “hot” EF and “cool” EF, with the expectation that these subtypes may be differentially linked to specific developmental outcomes.

**Hot Executive Functioning**

One aspect of EF is “hot” EF (Kerr & Zelazo, 2004). Hot EF is responsible for quick emotional processing. Quick emotional processing can be defined as a person’s immediate response to stimuli that have emotional content. Metcalfe and Mischel (1999) explain that the hot system can be thought of as a “go” system, or a system driven by one’s emotions. Hot EF is a fast processing system that is based on the ability to regulate one’s initial desires, affect, and motivation (Metcalfe & Mischel, 1999; Zelazo & Mueller, 2005). Children who are low in hot EF are impulsive, and act out with inappropriate behaviors such as talking out of turn (Brock, Rimm-Kaufman, Nathanson & Grimm, 2009). In contrast, children who are high in hot EF are better able to hold their emotional impulses in check so as to conform with social rules and conventions. Hot EF is necessary in the classroom setting, for example, because it allows students to wait for their turn, and to inhibit their drive to play instead of doing their classwork. As a result of their lack of drive inhibition, young children low in hot EF will perform poorly in the behavioral components that promote school success. Hot EF scores in preschool have been found to predict SAT scores in high school, as well at students’ grade point averages (Brock, Rimm-Kaufman, Nathanson & Grimm, 2009).

A classic means for measuring hot EF has been the "marshmallow task" (Mischel & Ebbesen, 1970). In this task, young children are presented with a marshmallow, and are advised that they can either eat it immediately, or wait for a period a time in order to receive a second marshmallow. Children's abilities to wait for the second marshmallow reflect the extent of their hot EF. That is, children who are less able to inhibit their delay responses are regarded as being weak in hot EF, whereas children who are capable of delaying their responses are considered to be high in EF. Children high in EF are also regarded as having better control over their emotional expressions. Other tasks to measure hot EF have included: (a) the gift wrap task, which requires that children watch a researcher wrap a gift, and then refrain from touching the gift; and (b) the whisper task, which requires that children whisper the names of cartoon characters that are shown on a series of cards (which reflects children's abilities to regulate voice intensity when they get excited; Kim, Nordling, Yoon, Boldt & Kochanska, 2013).

**Cool Executive Functioning**

In contrast to hot EF, cool EF refers to the allocation of attention and the inhibition of behaviors in the absence of emotional drive. Classically, a cool EF task involves some form of "switching," in which the parameters of successful task performance are changed midway through task completion. In one task, for example, children are first asked to sort small blocks into a small container, and large blocks into a large container (Carlson, 2005). After a pre-specified number of successful sorts, children are then asked to switch the rule and sort small into the large, and large into the small (reverse categorization). Children's abilities to follow the new rule reflect their capacity to inhibit a previously preferred (i.e., dominant) response. Children's abilities here represents "cool" EF performance because success does not depend on inhibiting an emotional impulse.

Other tasks used to measure cool EF performance have included motor inhibition tasks, which ask children to walk in a line as slowly as possible, or to draw a line as slowly as possible (Kim et al. 2013). These tasks require children to use their short-term memory, because they must remember the directions that were given to them to correctly complete the task, as well as the ability to inhibit their behavior.

Cool EF, as with hot EF, has been shown to be predictive of elements of school readiness. Brock et al. (2009), reported cool EF in the child's first year of elementary school to be predictive of reading, writing, math, and other behaviors necessary to learn in a classroom setting; as well as verbal comprehension in the second grade. Cool EF has also been found to predict early math and reading ability in 3 to 5 year olds (Blair & Razza, 2007). If cool EF has been linked to academic ability, then finding a deficit in the cool EF system is critical to identifying children at risk for poor academic performance.

**Executive Function and Language Development**

Given the findings above, there is plenty of reason to believe that EF may contribute to children's language development. As noted in the beginning, EF is composed of the abilities to allocate attention, to maintain items in short-term memory, and to inhibit dominant behaviors. At least the first two of these components should be relevant for children's language acquisition. As noted by de Abreu, Gathercole, and Martin (2011), for example, having a better working memory provides the means through which children can better detect, process, and map words and sentences produced in the environment to corresponding objects and activities taking place in the environment. Thus the extent to which children's short-term memories promote a recognition of the correspondence between the language heard and the activities taking place, individual differences in short term memory should correspond directly with language acquisition. Similarly, the extent to which children are able to allocate attention to linguistically relevant stimuli in the context of linguistic information, should also promote language acquisition.

Although connections between EF and language development make good theoretical sense, relatively few studies have investigated the potential relationship. Blair and Razza (2007) found that inhibitory control in EF predicts literacy in kindergarteners. Similarly, Im-Bolter, Johnson, and Pascual-Leone (2006) found that the ability of children to maintain attention lead to language competence. What remains to be uncovered is the extent to which hot versus cool EF are more strongly associated with language development.

**Hot Executive Functioning and Language Development**

Hot EF is linked to motivation, impulse, and affect (Walter & Mischel, 1999). To the extent that hot EF is linked to language development, it ought to be related to those aspects of language that are most strongly associated with emotionality. One aspect of language that seems especially linked to emotionality, is the desire to communicate goals and intentions to social partners. Those children who are successful at communicating their goals and intentions are likely to be satisfied and contented, whereas children who are communicatively unsuccessful are likely to be frustrated and discontented. Hot EF may come into play in this situation to the extent that children high in hot EF may be better able to regulate their impulsive reactions when their communicative efforts fail, thus providing them the emotional neutrality needed to strategize and develop alternative, and more successful linguistic approaches; whereas children low in hot EF, may be more likely to respond to communicative failures with impulsive and emotional reactions, which would in turn reduce their chances for reframing the situation and coming up with alternative linguistic approaches. In sum, individual differences in hot EF may contribute to individual differences in competent language productivity.

**Cool Executive Functioning and Language Development**

In contrast, cool EF has been linked to the ability to learn novel information (Brock, Kaufman-Rimm, Nathanson & Grimm, 2009) and the capability for letting new information update previously learned information (such as when new rules replace old rules in an EF switching task). Thus, to the extent that language acquisition involves the mapping of novel semantic and syntactic structures to corresponding objects and activities experienced in the social environment, cool EF ought to be particularly relevant for children's receptive language. Specifically, children high in cool EF ought to be relatively advanced in their receptive language repertoire, at least when compared to their low-cool-EF counterparts.

**Purpose of the study**

The purpose of this study is to explore the nature of the relationship between EF and linguistic competence, in children aged 3 to 4 years of age. Not only is EF generally expected to be associated with linguistic competence at this age, but the hot and cool subcomponents of EF are expected to be associated with different aspects of language acquisition. The three specific hypotheses include the following:

- H1: I hypothesize that executive function will be correlated with language development.
- H2a: Hot EF will be correlated with productive language.
- H2b: Cool EF will be correlated with receptive language.

## Methods

**Participants**

For my current investigation, I obtained a sample of 22 children between the ages of 36 and 60 (*M* age = 46.55 months *SD* = 7.39 months, *N* girls =15, *N* boys = 7). Children were recruited from a childcare facility affiliated with a local regional university. Eligible families were contacted by email, mail, or the center office; during which details of the study and the participation requirements were described.  Interested parents were invited to complete and return an IRB-approved Informed Consent Document. Children will be administered the PLS-4 task which will take approximately 30 minutes to complete. Children will then participate in the delay of gratification task.

## Materials and Tasks

Children were asked to engage in tasks that index hot executive function, cool executive function, and language acquisition.  Respectively, the children engaged in a "Delay of Gratification" task, a "Reverse Categorization" task, and the Preschool Language Scale, $4^{th}$ edition (PLS-4.)

**Behavioral Tasks**

*Hot EF.* As an index of hot EF a delay of gratification task was employed, based on the original "marshmallow task" described by Mischel (1987). In this task, the researcher placed one marshmallow in front of a child. The researcher told the child "you can eat this marshmallow now, or, if you wait until I come back into the room, I will give you two marshmallows." The researcher then walked out of the room for 5 minutes. Children who waited to eat the marshmallow until the researcher's return, were rewarded with a second marshmallow. This snack delay, or delay of gratification task served as a source of hot EF (Walter & Mischel, 1999). Children who are able to inhibit their response of wanting to eat the marshmallow are using their hot EF.

*Hot EF Measures of Interest.* To measure performance on the marshmallow task the extent to which children were able to tolerate a delay was measured. A range of scores were awarded based on consumption behaviors: a score of 0 was given if the child exhibited no consumption of the marshmallow, a score of 1 was giving if the child smelled the marshmallow, a score of 2 was given if the child picked the marshmallow with their fingers but did not eat the marshmallow, a score of 3 was given if the child licked the marshmallow, a score of 4 was given if the child picked and ate the marshmallow, a score of 5 was given if the child nibbled the marshmallow with their mouths, and a score of 6 was given if the child ate the entire marshmallow. Thus, higher scores indexed less delay tolerance. A score for delay tolerance was given every 5 seconds during a 5 minute task period. To evaluate consumption behaviors, both a maximum and mean score of delay tolerance was calculated.

*Cool EF.* To measure cool EF, I used a three dimensional version of the Dimensional Change Card Sort task (Stephens, Sabatos-DeVito, Brink, Raines, & Reznick, 2015; Zelazo, 2006). In this task, children were given a set of blocks, which could be categorized along either of two dimensions: by color (blue versus yellow) or by shape (round versus square). The researcher asked the child to sort the blocks first according to their color and then according to their shapes. When sorting by color, children were first asked to sort color-congruently (e.g., "place the blue blocks in the blue bowl and the yellow blocks in the yellow bowl"), and then color-incongruently (e.g., "place the blue blocks in the yellow bowl and the yellow blocks in the blue bowl"). The child was then asked to sort the blocks according to shape (e.g., "place the round blocks in the blue bowl and the square blocks in the yellow bowl"). Thus, Cool EF was indexed by the extent that children correctly placed the blocks in the requested buckets after the rule has been changed from the original.

*Cool EF Measures of Interest.* To evaluate children's performance on the cool EF block tasks 2 measures of interest were coded. First, two checks were performed to ensure children understood the tasks. The first check included a dichotomous score (e.g., yes or no) as to whether the child was administered the rule by the experimenter and waited until the completion of the rule to engage in the task (e.g., blue blocks go in the blue bowl, the yellow blocks go in the yellow bowl). Children were also required to restate the rule. The second check was also given a dichotomous score of yes or no as to whether the child restated the rule back to the experimenter. Two measures were then coded. The first measure was incorrect placements. Incorrect placements were defined as the child placing an item in the incorrect location. The second measure coded was corrections, which was defined as relocation of blocks as the child knew it was incorrectly placed. In addition, a global EF score was measured by obtaining the z scores of both hot and cool EF scores individually, and then adding the scores together.

**Language Task**

*Preschool Language Scale- 4th Edition.* Language development was derived from the Preschool Language Scale – 4th Edition (PLS-4; Zimmerman, Steiner & Pond, 2002). The PLS-4 measures both productive and receptive language, through a game-like format that involves props such as a block, a ball, a car, and a teddy bear. The PLS-4 is divided into two categories, labeled expressive and auditory. To measure productive language, the expressive communication subscale of the PLS-4 measure was used. The expressive communication subscale requires children to verbally respond to a question that a researcher asks. To measure children's receptive language the auditory comprehension subscale of the PLS-4 measure was used. The auditory subscale measures how children use motor activities (nodding and pointing) to respond to a question. The PLS-4 task was also used to index children's vocabulary, as well as their concepts of quality and quantity, analogies, and rhyming.

*PLS-4 Measures of Interest.* Based on children's performance on the PLS-4, three measures were computed using the manualized procedures. The first measure computed was that of Auditory Comprehension (AC). As defined in the PLS-4 Examiner's Manual, "the AC subscale is used to evaluate how much language a child understands. The task designed for preschool aged children assesses comprehension of basic vocabulary, concepts, and grammatical marker" (PLS-4: Zimmerman, Steiner, & Pond, p. 2). The second measure utilized from the PLS-4 is that of Expressive Communication (EC). EC "is used to determine how well children communicate with others. Preschool aged children are asked to name common objects, use concepts that describe objects and express quantity, and use specific prepositions, grammatical markers, and sentence structures" (PLS-4: Zimmerman, Steiner, & Pond, p. 2). Consistent with the procedures identified in the PLS-4 manual, a final score, the Standard Total Score, was calculated as a sum of both the AC and EC.

## Results

### Descriptive Statistics

Means and standard deviations for all the variables of interest for language development and EF are presented in table 1. In addition, an overall EF measure was obtained by creating z-scores for delay tolerance mean and for the incongruent incorrect placements (blue blocks yellow bowl, yellow blocks blue bowl); I then added the two measures together ($M$ = 0.00, $SD$ = 1.39).

Table 1

*Descriptive Statistics*

| **Measure** | **Mean** | **SD** | **Min** | **Max** | **N** |
|---|---|---|---|---|---|
| Overall EF | 0.00 | 1.39 | 0 | 6 | 2 |
| Hot EF | | | | | |
| Delay Maximum | 1.59 | 2.26 | 0 | 6 | 22 |
| Delay Mean | 0.45 | 1.29 | 0 | 6 | 22 |
| Cool EF | | | | | |
| Total Incorrect BBYY | 0.52 | 0.98 | 0 | 4 | 21 |
| Total Corrections BBYY | 0.62 | 1.12 | 0 | 4 | 21 |
| Total Incorrect BYYB | 1.18 | 1.40 | 0 | 5 | 22 |
| Total Corrections BYYB | 1.05 | 1.43 | 0 | 5 | 22 |
| Total Incorrect Shape | 1.73 | 3.51 | 0 | 12 | 22 |
| Total Corrections Shape | 0.41 | 0.79 | 0 | 3 | 22 |
| Language Measures | | | | | |
| PLS-4 Receptive | 119.50 | 12.50 | 89.0 | 141 | 22 |
| PLS-4 Productive | 115.14 | 16.28 | 77.0 | 142 | 22 |
| PLS-4 Standard Score Total | 119.36 | 14.96 | 81.0 | 146 | 22 |

EF = executive function; BBYY = blue blocks blue bowl, yellow blocks yellow bowl; BYYB= blue blocks yellow bowl, yellow blocks blue bowl

## Inferential Statistics

The next section of analyses represents tests of the hypotheses outlined in the introduction. As can be seen in Table 2, and in line with H1, correlational analyses between EF measures and language scores were conducted. Results confirmed expectations that EF would be correlated with total language. However, surprisingly, EF was not significantly correlated with either receptive or productive language individually.

To investigate Hypotheses 2a and 2b, additional correlations were calculated between each of the two types of executive function and each of the two types of language measures. The first predictive measure considered was that of delay tolerance among children within the hot EF task. Two scores were derived: maximum delay tolerance and mean delay tolerance. Maximum delay tolerance was not significantly related to any of the language outcomes of interest. However, mean delay tolerance, which is reported as the "hot" measure in Table 2, was correlated with all three language development measures. Hot EF was overall negatively related to all three of the language measures of interest from the PLS-4, indicating that higher mean delay tolerance scores (reflecting less delay tolerance) were associated with lower productive, receptive, and total language. In sum, Hypothesis 2a was supported, as hot EF was significantly related to productive vocabulary.

In contrast, Hypothesis 2b was not supported. Although it was expected that cool EF would be related to receptive language, this was not the case.

Table 2

*Correlation between EF measures and language measures*

| **Language Measures** | **Cool** | **Hot** | **Overall** |
|---|---|---|---|
| Productive | -0.179 | -0.507* | -0.493* |
| Receptive | 0.032 | -0.489* | -0.328 |
| Total Language | 0.058 | -0.532* | -0.424* |

* = $p < 0.05$

Cold= Total incorrect placements by child during BYYB

Hot = Mean delay tolerated

Overall = z scores for both hot and cool EF measures were added together

## Discussion

The goal of this study was to explore associations between EF and language acquisition in preschool aged children, with a particular focus on whether hot or cool components of EF were uniquely associated with components of language. That there would be potential EF-language associations stood to reason to the extent that the component abilities of EF, including attention allocation, maintenance of items in short-term memory, and inhibition of dominant responses, should all contribute to language acquisition.

Within the current study there were three specific hypotheses. It was hypothesized (H1) that executive function would be correlated with language development. This expectation was confirmed, but only by virtue of the fact that hot EF, which was a component of Overall EF, was correlated with both the productive (confirming H2a) and total language measures. Cool EF was not associated with any language measures, thus disconfirming H2b.

Hot EF may be linked to language acquisition because elements that are important in modulating language have significant emotional components. Thus, the intention to communicate linguistically may carry with it a desire to be successful, and children who are better able to modulate emotion-laden intentions may be especially successful in producing effective language. It is not clear why cool EF was not also associated with language performance. It could be that the kind of cognitive functioning which is reflected in cool EF, and that has been associated with school readiness in previous research, may be considerably different than the cognitive functioning needed for language. Future research should focus on this differentiation as a means to better understanding variability in both language and other cognitive outcomes early child development.

There were several limitations to the present investigation. First, the small sample size surely provided low statistical power to detect some of the hypothesized effects. On the other hand, this sample size is comparable to other developmental studies. The present research was also limited to associations observed at 3 and 4 years. It is unclear the extent to which similar associations would be observed in older or younger children. It would be particularly interesting to investigate these relationships in younger children, to the extent that EF-language associations may emerge in the very earliest periods of language acquisition such as first word acquisition and first word combinations. EF may even play a causal role in language acquisition during the earliest stages. Unfortunately, efforts to develop measures of EF in the first two years of life appear to have proved unsuccessful. To date, there are no measures of EF appropriate for children younger than about two years of age (Carlson, 2005).

Another potential limitation is that only one measure of each of component of EF was performed. Before broad conclusions regarding the relationship between children's EF and language ability can be made, additional measures of hot and cool EF should be considered. Our findings are preliminary and were only tested with one hot task. Carlson (2005) suggests that other hot tasks such as gift delay or the whisper task are good measures for children 3 years and younger. As noted by Kochanska, Coy, and  Murray (2001), children's performance on one task doesn't necessarily mean they do well on other tasks, which could be related to the uniqueness of tasks. Research should determine whether significant findings extend beyond the marshmallow tasks and whether non-significant findings extend beyond the sorting-switching task employed in the present study.

To my knowledge, this is the first study to document an association between exclusively hot EF and language acquisition. The current work helps fill some of the gaps in the extant literature examining the relationships between EF and language ability in preschool aged children. The most unique aspect of the study is that children's delay tolerance is predictive of their language ability. So, children who engage in impulsive consumptive behaviors also appear more likely to have less language ability than a child who does not engage in these behaviors. Confirmation of this relationship raises the possibility that providing children with opportunities to control their impulsive consumptive through some means of intervention training, may also improve their capacity for language acquisition.  .

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