The Role of Executive Functions in Children's Communication Repair

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

Young children often provide ambiguous referential statements for their listeners. Thus, the ability to identify when miscommunication has occurred and subsequently repair messages is an essential component of communicative development. The present study examined the impact of listener feedback and children's executive functioning in influencing children's ability to repair their messages. Further, this work explored whether the cognitive demands of repair differed depending on the type of feedback provided by the listener. Children (ages 4 to 6) completed a referential communication task, in which they described target pictures amongst an array of similar distractors for a confederate. Stimuli were designed such that children would often provide initially ambiguous referential statements. Subsequently they were provided with feedback from the confederate indicating they had been misunderstood. Feedback was either detailed and specified the nature of the miscommunication, or was vague and did not. Children also completed executive functioning tasks assessing their working memory, inhibitory control, and cognitive flexibility. Children with larger working memory capacities and better cognitive flexibility were found to provide more effective initial descriptions of the target pictures. Children with better cognitive flexibility were also more effective at repairing their statements in response to feedback indicating they had been misunderstood. While children provided more effective repairs following detailed feedback than vague feedback, this effect did not interact with the cognitive skills of the children. The practical implications of the results are discussed.

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Literature Review

Much of human communication is dedicated to the exchange of information, which often requires references to people, objects and places in the world. This skill, known as referential communication, encompasses basic communicative acts such as requesting an object as well as more complex acts such as directing a neighbour to a restaurant, using a map, or instructing a colleague on how to use new computer software. As with most communicative exchanges, referential communication involves intricate coaction between the speaker and the listener, with both interlocutors playing an active role. While the roles of the speaker and listener are arguably of equal importance, this literature review will focus on the skills associated with the speaker. In particular, this review will chart the development of children's ability to act as effective speakers; that is, the ability to produce comprehensible yet succinct statements for a listener. Since there is much ambiguity in our language, particularly within young children's statements, the possibility for misunderstandings is high, and the ability to identify when miscommunication has occurred and to repair one's statement is a critical aspect of learning to be a successful speaker. As such, this review will highlight the development and cognitive skills associated with both initial utterances and repair statements. This review will highlight the skills of preschool-aged children between the ages of 4 to 6, an important point in the development of children's skills as speakers; however, in order to add context to the development of these communicative skills, this review will also refer to literature across the lifespan.

Effective Communication

Before discussing the development of effective speaker skills it is important to first clarify what constitutes effective communication. Grice (1975) believed that conversation between two individuals is cooperative in nature and proposed several maxims individuals abide by while engaged in a conversation to ensure effective communication. These maxims fell under four categories: Quantity, Quality, Relation, and Manner. The maxims that are most relevant to referential communication are the maxims of Quantity and Manner.

The maxim of Quantity posits that one should "(1) Make your contribution as informative as is required" and "(2) Do not make your contribution more informative than is required" (Grice, 1975, pp 45). Essentially the maxim of Quantity qualifies the *amount* of information necessary for an effective message. An effective message should not provide redundant information, but should provide enough information that it is comprehensible by another person. Unlike the maxim of Quantity, the maxim of Manner relates more to *how* one's message is said rather than to *what* is said. The maxim of Manner posits that one should "(1) Avoid obscurity of expression; (2) Avoid ambiguity; (3) Be brief (avoid unnecessary prolixity)" and "(4) Be orderly" (Grice, 1975, pp 46). Overall, this maxim proposes that a speaker should try to make their messages as easy as possible for the listener to understand, using clear and organized language. As will be discussed further, young children often fail to provide enough information for their listeners, reflecting a failure to follow the maxims of Quantity and Manner. As a result, young children tend to produce ambiguous messages for their listeners.

Development of Referential Communication

Although the complexity and success of children's communication shows continual development throughout the school-age years, rudimentary referential communication is demonstrated at a very young age. By their first birthday, infants are able to communicate about objects in their world by pointing at them (Liszkowski, Carpenter, Striano, & Tomasello, 2006; Tomasello, Carpenter & Liszkowski, 2007). Infants point to objects in order to request them, to draw a listener's attention to the object, or even to help another person to find an object they are looking for (Liszkowski, et al., 2006). Infants also begin to produce their first words around the age of 12 to 13 months (Fenson et al., 1994). These first words typically include the names of familiar people or objects. The act of using these names to refer to objects and people in their space are evidence of progression to linguistic forms of referential communication.

Much of the research on children's referential communication has used variations of a paradigm developed by Glucksberg, Krauss and Weisberg (1966; based on a paradigm developed by Krauss and Weinheimer, 1964; See Dickson, 1982 for a review). This paradigm, known as the referential communication paradigm, involves having a participant describe a target object within a larger set of similar objects for another person. The two people are typically separated by some form of visual barrier so that only verbal means of communication may be used. The quality of the speaker's message to the listener is then assessed. If the speaker's message does not uniquely identify a target referent for the listener, it would be coded as ambiguous. For example, the speaker's message would be considered ambiguous if he/she told the listener to "pick up the green triangle," when the set of objects contained a large and a small green triangle.

While children show rudimentary abilities to refer to objects, as noted above, a substantial amount of research has found that young children around the ages of 4- and 5-years-old perform quite poorly on the classic referential communication tasks (e.g. Glucksberg et al., 1966; Krauss & Glucksberg 1969; Lloyd, Mann, & Peers, 1998; Pechmann & Deutsch, 1982). For example, Glucksberg et al. (1966) found that children between the ages of 3 and 5 were unable to provide unambiguous descriptions of abstract symbols for a listener their age, while adults were able to do this successfully (Krauss & Weinheimer, 1964).

Children's accuracy in producing unambiguous referential statements improves gradually between the ages of 5 and 10 (Krauss & Glucksberg, 1969; Lloyd et al., 1998; Pechmann & Deutsch, 1982). For example, Lloyd and colleagues found that children's ability to produce unambiguous messages increased rapidly between the ages of 5 and 7. However, even by the age of 11-years-old, children were found to provide unambiguous descriptions of target referents on only 66% of trials. This shows that the development of children's skills as speakers continues well into their school-age years.

A number of researchers have posited that children have difficulty producing unambiguous messages for their listeners because they are not able to discriminate between ambiguous and unambiguous messages (Whitehurst, Sonnenschein, & Ianfolla, 1981). Thus, a child may think her referential intent (e.g., the large green triangle) is clear for a listener even when her message is not (e.g., requesting the "green triangle" when there are two green triangles of different sizes). Along these lines, past research has shown that young children tend to blame listeners rather than speakers for miscommunication that follows an ambiguous message (Robinson & Robinson, 1977).

However, more recent studies find that late preschool-age children show sensitivity to communicative ambiguity when it is presented in a third-person perspective task (Nilsen, Graham, & Smith, 2008; Nilsen & Graham, 2012). That is, when children observe a speaker providing an ambiguous message to a listener during a referential communication task, they demonstrate implicit behaviour (e.g., eye gaze, response latency) that suggests they appreciate that there may be confusion as to which object the speaker is attempting to identify. Other recent work has demonstrated that preschool-aged children prefer to obtain information from unambiguous speakers (Gillis & Nilsen, 2013). Thus, it may be the case that while children recognize when messages are unclear, the processing demands of actually producing statements may be too great for messages to always be at the level of detail needed for a listener.

Skills that Contribute to Referential Communication

Communicative perspective-taking. As was previously mentioned, an effective statement for a listener should provide the information necessary to be comprehensible without being redundant or overly lengthy (Grice, 1975). In order to know how much information to provide, a speaker needs to take the listener's perspective into account; specifically, the speaker needs to account for the listener's knowledge state. For example, if my neighbour who is familiar with the area in which we live asked me the best route to a nearby restaurant, I would likely provide very different directions than I would if asked the same thing by someone visiting from out of town. Using such information about a communicative partner's perspective to guide communicative behaviour is known as communicative perspective-taking (see Nilsen & Fecica, 2011 for a review). Communicative perspective-taking is required for effective referential communication.

Indeed, past work has found that children with better communicative perspective-taking skills provide more effective messages for their listeners in referential communication tasks (Roberts & Patterson, 1983), especially when the task is intrinsically motivating and children are requesting objects as part of a game (James, 2001; Resches & Pereira, 2007). Failing to make use of a communicative partner's perspective can result in miscommunication. For example, in a classic referential communication task where the same objects are visible to both the speaker and the listener, the speaker would be likely to provide an ambiguous message if they fail to recognize that although they themselves know the correct target, the listener does not have this information and thus may be confused by objects besides the target.

Piaget (1926) proposed that young children fail to provide enough information for their listeners because children under the age of 7 are "egocentric", and thus unable to consider the perspective of another person. However, an inability to consider another person's perspective likely does not account for the poor performance seen in young children on the referential communication task. The referential communication task requires that children have access to a listener's knowledge state based on what they can or cannot see. This type of perspective-taking is one that children typically demonstrate at a young age (e.g. Luo & Baillargeon, 2007; Poulin-Dubois, Sodian, Metz, Tilden and Schöppner, 2004; Liszowski et al 2006; Sodian, Thoermer, & Metz, 2007; see Baillargeon, Scott, & He, 2010 for a review). For example, 12.5-month-old infants are able to track the objects another person can see, and use this information when interpreting their actions (Luo & Baillargeon, 2007).

By four years old, children also demonstrate sensitivity to listeners' characteristics, as evidenced by speaking differently (i.e., longer messages) to an adult compared to a younger child (Shatz & Gelman, 1973). Additionally, 5-year-olds are able to account for their listener's needs when producing referential statements in a modified referential communication paradigm, in which the number of objects in the array was reduced. For example, in a study by Nadig and Sedivy (2002), 5-year-olds were asked to describe target objects in a display case to a listener, with some objects blocked from the listener's view. The children demonstrated that they were able to consider which objects the listener could and could not see when producing their descriptions of the target. Children provided more detailed descriptions of the target (e.g. a large glass) when a similar object (e.g. a small glass) was visible to the listener compared to when the similar object was blocked from the listener's view (see Nilsen & Graham, 2011 and Wardlow & Heyman, 2016 for similar findings).

Executive functions. As alluded to earlier, children may have difficulty acting as effective speakers in certain contexts due to the cognitive demands associated with effective communication. One area which may limit children's ability to produce successful referential statements is their executive functioning. The term executive functioning refers to cognitive skills that control and regulate other lower-level cognitive processes as well as goal-directed behaviour (Alvarez & Emory, 2006). Executive functions consist of several components: such as working memory, which refers to the ability to hold in mind and mentally manipulate information; inhibitory control, which refers to the ability to withhold a dominant response; and cognitive flexibility, which refers to the ability to think flexibly and switch one's way of thinking about a problem.

There are many different models describing the structure of executive functions in adults. One of the more dominant models in the literature is Miyake and colleagues' (2000) Unity and Diversity framework (see Friedman et al., 2008 for an example of an alternative model). In a factor analytic study, Miyake and colleagues found three separable yet related components of executive functions: mental set shifting, information updating and monitoring, and inhibition of prepotent responses. These three components correspond to cognitive flexibility, working memory and inhibition, which were discussed previously.

The existing literature on young children's executive functions suggests that elementary forms of these three components of executive functioning exist in preschool-aged children, ages 3 to 5 (Garon, Bryson & Smith, 2008); however, there is currently no consensus on the structure of executive functions in young children. That is, some research suggests that executive functioning in young children is an undifferentiated resource, meaning that all components of executive functioning are highly related and load onto the same factor (Brocki & Bohlin, 2004; Hughes, Ensor, Wilson, & Graham, 2010; Nilsen, Huyder, McAuley, Leibermann, 2016; Weibe et al., 2011). Other work suggests that young children's executive functioning consists of two broad components of working memory and inhibition. Within this framework, tasks measuring cognitive flexibility would load onto the working memory component (Miller et al., 2012; Müller & Kerns, 2015).

Children's executive functioning improves with age (Garon et al., 2008). Although children demonstrate the beginnings of executive functioning during infancy, each component of executive functioning shows its own developmental trajectory (Best, Miller, & Jones, 2009; Garon et al., 2008). Many studies have found that children's performance on Stroop-like tasks, which are thought to measure inhibitory control, improve dramatically between the ages of 3 and 7 years old (e.g. Carlson, 2005; Diamond, 2002; Simpson & Riggs, 2005). Children are thought to reach adult levels of performance on inhibitory control tasks by age 12 (Huizinga, Dolan & Molen, 2006). Working memory appears to develop more slowly, with children's performance on a variety of working memory tasks improving gradually between the ages of 4 to 15 (Best et al., 2009; Gathercole, Pickering, Ambridge, & Wearing, 2004). Similarly, cognitive flexibility improves gradually with age until early adolescence (Best et al., 2009; Huizinga et al., 2006). Despite the growth of executive functioning during the preschool and school-age years, studies have found that many aspects of executive functioning continue to develop well into adolescence (Best et al., 2009; Blakemore & Choudhury, 2006; Huizinga et al., 2006).

Executive functioning is thought to play a role in facilitating children's effective communication (Nilsen & Fecica, 2011). Specifically, executive functioning is thought to support the *use* of information about a communicative partner's perspective for guiding communicative behaviours. For example, in order to produce a message that is tailored to one's listener, a speaker would need to hold information about their listener's perspective in working memory while they are formulating their message. A speaker may also need to inhibit their own perspective in order to take a communicative partner's perspective into account. Cognitive flexibility may also play a role in speakers' production of effective statements because an effective speaker must be able to think flexibly about their message, and tailor their message to be most effective for their listener.

Indirect support for the notion that executive functioning is implicated in children's referential communication can be gleaned through a comparison of various tasks. Earlier referential communication tasks, which used a greater number of stimuli and objects which varied on a greater number of dimensions (e.g. Glucksberg et al., 1966; Krauss & Glucksberg 1969; Lloyd et al., 1998; Pechmann & Deutsch, 1982), have yielded worse performance from children than later tasks that have reduced the cognitive demands (such as limiting the dimensions of the objects and the number of distractor objects; e.g. Nadig & Sedivy, 2002; Nilsen & Graham, 2009). A more direct examination of the effect of varying cognitive demands comes from adult studies in which participants are placed under a cognitive load. Adults have more difficulty accounting for their listener's perspective when they are under a cognitive load or time pressure (Horton & Keysar, 1996; Roßnagel, 2000, 2004). Such a finding suggests that when an individual's cognitive resources are depleted, they tend to resort to a more egocentric form of communication where they fail to consider the needs of the listener, thereby producing ambiguous utterances.

Clinical populations who are impaired in executive functioning, such as those with attention deficit hyperactivity disorder (ADHD; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2015) or autism (Ozonoff, 1995) also demonstrate impairments in their communication skills, providing further support that executive functions may be required for effective communication. For instance, individuals with ADHD (Green, Johnson, & Bretherton, 2014) and autism (Young, Diehl, Morris, Hyman, & Bennetto, 2005) demonstrate pragmatic language difficulties, meaning they have difficulty communicating effectively in social contexts. Several studies have found an association between the executive functioning and communication difficulties seen in individuals with ADHD (Bunford, 2015; Huang-Pollock, Mikami, Pfiffner, & McBurnett, 2009; Kofler, 2009; Tseng & Gau, 2013). Past research has also found associations between executive functioning and deficits in social behaviour in individuals with autism (McEvoy, Rogers, & Pennington, 1993). Thus, it appears that a weakness in executive functions may explain the communicative deficits seen in these clinical populations.

Studies examining individual differences in executive functioning in relation to communication provide further support for the role of executive functioning in facilitating effective communication. For example, past work has found that speakers' inhibitory control and working memory skills are related to their ability to account for their listeners' needs when producing statements (Nilsen, Varghese, Xu, & Fecica, 2015; Wardlow, 2013). In particular, Nilsen and colleagues found that 9- to 12-year-old children with larger working memory capacities provided more information that could be used to disambiguate the target object from distractors in a referential communication task. Similarly, Wardlow (2013) found that adults with better working memory were able to tailor their messages based on whether or not objects similar to the target object were in view of the listener. For example, if the target were a small circle, speakers with strong working memory were more likely to use modifiers (e.g. "small") when both a small and large circle were visible to the listener. In comparison, speakers with strong working memory were less likely to use modifiers when the distractor object similar to the target was blocked from the listener's view, and thus visible to only themselves.

Executive functioning has also been found to relate to *listeners'* ability to account for a speaker's perspective when interpreting messages. For example, in a study by

Nilsen and Graham (2009), preschoolers followed instructions from a director as to which objects to move in a display case. Preschoolers with stronger inhibitory control were less likely to interpret the director's instructions as referring to objects that were blocked from the director's view, which she could not see (see Brown-Schmidt, 2009 for similar results with adults). Additionally, adults with larger working memory capacities were found to consider the speaker's perspective to a greater extent than those individuals with weaker working memory (Lin, Keysar & Epley, 2010).

Together, research supports the notion that while perspective-taking is an essential component of producing effective referential statements, this skill alone may not be sufficient for ensuring that statements are unambiguous. Rather, speakers require the executive functioning skills to support the generation of clear, unambiguous statements for listeners.

Communication Repair

As discussed previously, young children often fail to provide enough information for their listeners (e.g. Lloyd et al., 1998). Further, it seems that even adults do not automatically take their listener's perspective into account (see Keysar, 2007 for a review). Keysar and colleagues (Horton & Keysar, 1996; Keysar, 2007) posit that speakers start from an egocentric standpoint, but then tailor messages to their listener's needs by monitoring and correcting their planned utterances for errors. Thus, producing statements is thought to be a two-stage process. The second stage of this process appears to be disrupted when the cognitive demands of communication are increased (Horton & Keysar, 1996; Roßnagel, 2000, 2004). However, this process appears to work effectively most of the time in adults (at least within referential communication), as they are usually able to produce effective messages for their listeners (Engelhardt, Bailey & Ferreira, 2006). Following this model, the ability to monitor planned messages for errors and correct these errors remains critical for effective communication across the lifespan.

It is possible that children develop the streamlined monitoring and repair process seen in adults through first learning to recognize when miscommunication has occurred (which would subsequently prompt them to repair their messages). Children demonstrate some ability to do this from a very young age. For instance, preverbal infants try to use pointing and vocalizations to repair messages that have been misunderstood by their mother (Golinkof, 1986). Additionally, 12- to 18-month-olds continue to point at objects if the recipient of their pointing fails to look at what they were trying to draw their attention to (Liszkowski, Albrecht, Carpenter, & Tomasello, 2008).

While young children *attempt* to repair their messages, there are mixed results regarding the *effectiveness* of communication repair in preschool-aged children. O'Neill and Topolovec (2001) found that when two-year-olds were asked for clarification by an experimenter, they tended to use ineffective repair strategies. For example, the children pointed to an object they had requested, even when the objects near the desired object were placed such that it could not be uniquely identified through pointing. However, several other studies have found that preschool-aged children are able to improve the clarity of their original messages following feedback indicating they have been misunderstood (e.g. Coon, Lipscomb, & Copple, 1982; Deutsch & Pechmann, 1982; Nilsen & Mangal, 2013). For example, in a study by Deutsch and Pechmann (1982), children (ages 3, 6, and 9) were asked to describe objects for an experimenter in a referential communication task. When children provided an ambiguous description of the target, the experimenter requested clarification (e.g., if the child asked for the “red ball” and there was both a large and small red ball, the experimenter would ask, “which ball?”). In this study, 3-year-olds were able to successfully repair their messages and uniquely identify the target for the experimenter on 89% of trials. As will be discussed further, several studies have also shown that children are able to benefit on subsequent trials from feedback indicating their messages were inadequate (Abbot-Smith, Nurmsoo, Croll, Ferguson & Forrester, 2015; Lefebvre-Pinard, Charbonneau, & Fider, 1982; Matthews, Lieven, & Tomasello, 2007; Matthews, Butcher, Lieven, & Tomasello, 2012; Robinson & Robinson, 1981; 1985; Wardlow & Heyman, 2016). That is, children’s subsequent attempts at identifying referents for a listener improve following feedback indicating they have been misunderstood.

Type of feedback for children’s repairs. The type of feedback that listeners provide is important in determining the degree to which children will be able to modify their messages. For example, in a study by Coon and colleagues (1982) 5-year-old children completed a referential communication task where they described target pictures for an experimenter. When the children generated ambiguous messages, they were provided one of several different types of feedback by the experimenter: either solely verbal feedback, or verbal feedback while being shown the experimenter’s incorrect object choice. In the latter feedback, the incorrect choices were objects that matched the child’s ambiguous message, but were not the target object. There were also three varying levels of feedback specificity within these two categories of feedback, resulting in a total of six types of feedback. For example, the least specific feedback involved the experimenter indicating they chose the incorrect object and saying, “Tell me whatever I need to know to pick the right one." For the most specific feedback, the experimenter said a variation of the following: "There were severa1 red ones and I picked the wrong one. I picked a red circle." Specific feedback was modified based on the children's original statements. Results demonstrated that children were able to modify their statements most effectively following the highly specific feedback, or when shown the experimenter's incorrect object choice.

Similar effects of feedback type have been reported in other studies. For example, Anselmi and colleagues found that children (ages 1 year; 8 months to 3 years; 8 months) typically repeated their original ineffective messages following vague feedback (e.g. "what?" or "huh?"), but were able to provide clarification following specific queries about their statements (Anselmi, Tomasello, & Acunzo, 1986; see Wilcox & Webster, 1980 for similar findings). Nilsen and Mangal (2013) also found that 3- to 4-year-olds tended to repeat themselves following vague feedback. Similar to Coon and colleagues (1982), Nilsen and Mangal found that children were more effective in repairing their messages when they were shown the listener's incorrect object choice. In contrast, Fagan (2008) found that children were likely to abandon their attempts to get their message across when they were provided with a toy that was not the one they were attempting to request. However, this result may have occurred because children were not requesting specific objects to meet a goal as in Nilsen and Mangal or Coon and colleagues, where children were told to describe a specific target to the experimenter. Instead, in Fagan's study, children were spontaneously requesting toys during free play so might not have cared which specific toy they were given.

Together, these studies suggest that children are usually motivated to get their messages across, as evidenced by their attempt to repair their messages. However, it appears that children have difficulty repairing their messages following vague feedback, and that more specific feedback facilitates their ability to repair their messages.

Training studies of communication repair. Repairing statements in response to feedback from a listener may be an important way through which children learn to be effective communicators. Robinson and Robinson's (1981) longitudinal work supports this notion. These researchers recorded conversations between mothers and their preschool-aged children, and identified mothers who occasionally explicitly told their child when they did not understand what they meant. Children were then tested when they were 6 years old. The children described specific pieces of clothing for a doll out of a larger set of similar clothing for an experimenter, in order for her to dress her doll in a matching fashion. Following ambiguous messages, the experimenter asked the child who was to blame for the miscommunication, to give reasons for why this person was to blame, and to judge whether he or she provided enough information about the clothing. Children of mothers who more frequently indicated when they were not understood (during the preschool years) were better at accurately answering these questions about message ambiguity later, when they were 6 years old.

Several studies have focused on providing children with feedback and giving them the opportunity to repair their statements as a way of training them to provide more effective messages for their listeners. In two studies by Matthews and colleagues (2007; 2012), preschool-aged children requested specific pictures out of an array of pictures from an experimenter. The children used these pictures in order to make a sticker book they were given with missing stickers match a completed version of the sticker book. Following an ambiguous request, the experimenter provided either generic (e.g. Which girl?) or specific (e.g. Is it the girl dancing or the girl singing?") feedback. Children of all ages (2.5, 3.5, and 4.5 years) provided more effective referential statements on subsequent trials, and they learned to do this more quickly following specific feedback. Matthews and colleagues' 2007 study also included conditions where instead of requesting stickers themselves, the children responded to an adult's requests for stickers, observed an adult asking for stickers from another adult, and heard example descriptions of stickers from an adult. While all conditions improved children's effectiveness as speakers, children improved the most when requesting the stickers from an adult themselves. This suggests that children learn to become effective speakers best when they produce a message, are provided with feedback, and are given the opportunity to repair their messages (see Abbot-Smith et al., 2015; Lefebvre-Pinard et al., 1982; Robinson & Robinson, 1981; 1985; Wardlow & Heyman, 2016 for similar findings).

In sum, feedback is used by children to repair their initial statements (albeit sometimes imperfectly) as well as to improve on subsequent statements. The type of feedback impacts both of these processes. Examining communication repair in atypical populations has also provided insight into the skills required for effective communication repair.

Communication repair in clinical populations. A number of studies have examined communication repair in clinical populations, such as individuals with autism, schizophrenia and epilepsy. Individuals with autism and a diagnosis of pervasive developmental disorder (PDD) were found to be impaired in communication repair (Paul

& Cohen, 1982; Volden, 2004). For instance, in a study by Volden (2004), children were engaged in conversation with an experimenter, during which the experimenter interjected requests for clarification to create a communication breakdown. These requests were interjected regardless of the effectiveness of the children's initial messages. Requests for clarification were stacked such that participants received three sets of increasingly specific feedback (i.e. 1. "What?"; 2. "I don't understand"; 3. "Tell me in another way"). Consistent with previous work (e.g. Coon et al., 1982), children's repair strategies varied depending on the feedback provided. Children (regardless of diagnosis) were most likely to repeat themselves following vague feedback (i.e. "what?") and were most likely to provide additional information when the experimenter told them, "I don't understand." Children with autism or PDD were more likely than typically developing control participants to respond to requests for clarification inappropriately. That is, these children tended to provide responses that included an off-topic remark or attempted to end the interaction.

Work by Caplan (1996; 2001) found that children with schizophrenia and epilepsy are impaired in self-initiated communication repair. Self-initiated repair occurs when an individual notices a communication breakdown has occurred in the absence of receiving feedback, and modifies their message. In both studies, Caplan took speech samples of children explaining a story to an experimenter. He found that children (aged 5 to 12) with schizophrenia were less likely than typically developing children to clarify the referent they were speaking about (Caplan, 1996). Also, while typically developing children tended to use a wider variety of repair strategies with age, children with epilepsy did not do this and tended to overuse certain repair strategies, such as clarifying the referent they were speaking about, or changing the syntax of their statement (Caplan, 2001). These self-initiated repair strategies were determined by the researchers to be less effective than those used by typically developing children. While self-initiated repair is different from communication repair following feedback, in that the child is required to monitor their own statement and determine that a communication breakdown has occurred, these results suggest that within some clinical populations, repair is impaired.

Although speculative given the lack of research in this area, one possible reason that some clinical populations are impaired in communication repair may be that repair requires cognitive resources such as executive functioning. Indeed, previous work has shown that individuals with autism (Ozonoff, 1995), schizophrenia (Sullivan, Shear, Zipursky, Sagar, & Pfefferbaum, 1994), and epilepsy (Hernandez et al., 2002) are impaired in executive functioning.

Communication repair and executive functions. The role of specific cognitive skills in children's ability to repair their messages following feedback is unclear, although some researchers have hypothesized that executive functioning plays a role. Volden (2004) proposed that communication repair involves three main steps: "(1) an ability to judge another person's state of knowledge; (2) a comparison of the listener's perceived state of knowledge with the speaker's original utterance and a subsequent determination about what components of the original message were inadequate; and (3) an adjustment to the speaker's utterance that is based on steps 1 and 2." It is evident from past research that preschool-aged children are somewhat capable of step 1: judging the listener's knowledge state (e.g. Nadig & Sedivy, 2002; Nilsen & Graham, 2009). Volden suggested that steps 2 and 3 may involve working memory, since a child would need to judge the listener's knowledge state and compare the listener's perceived knowledge state to their original statement, then determine what was unclear about their original statement. All of this information would need to be held in working memory until the child produces a modified statement. It is possible that inhibition and cognitive flexibility could play a role in communication repair as well. That is, step 1 may involve inhibition, since the child may need to inhibit their own perspective in order to take the listener's perspective into account (although this inhibition would need to be maintained in steps 2 and 3). Additionally, step 3 may require cognitive flexibility, as the child would need to modify their original statement rather than repeating it.

The hypothesis that executive functioning plays a role in children's communication repair is consistent with studies which found that children are better able to repair their messages when provided with detailed feedback or when shown the listener's incorrect object choice (Anselmi, et al., 1986; Coon et al., 1982; Nilsen & Mangal, 2013). That is, the benefit specific feedback may provide over other forms of feedback is that it reduces the cognitive demands of repair (Coon et al., 1982). For example, when a child receives specific feedback or is shown the listener's incorrect object choice following an ambiguous message in a referential communication task, the child only needs to compare their original message with the referent identified by the listener. When a child is provided with vague feedback the child is required to compare his or her statement with all the possible referents in the array in order to determine specifically what was lacking with the original message. Thus, detailed feedback could possibly reduce the amount of information the child needs to hold in working memory. In addition, detailed feedback may make the perspective of the listener more obvious, making it easier for the speaker to inhibit their own perspective in order to take the listener's perspective into account. Further, detailed feedback may reduce the demands on cognitive flexibility by making it more salient which dimensions of the target object the listener is confused about and making the aspects of the object which a child needs to think flexibly about (i.e., that the object is both red and large, etc.) more obvious. Although theoretically this makes sense, the cognitive demands associated with repair following vague feedback compared to detailed feedback have not been examined empirically.

While past work has charted the role that executive functioning has for the production of referential statements, no studies have directly assessed the cognitive demands associated with children's ability to repair their messages in response to feedback. Children's ability to benefit from feedback in order to produce more effective subsequent messages may reflect a different process than their ability to repair their initial messages following feedback. Specifically, repairing initial messages involves responding to situations in the moment and involves consideration of one's own original message as well as the listener's feedback. In contrast, benefitting from previous feedback to produce more effective messages involves learning about what constitutes effective communication; a skill which can be carried forward into subsequent acts of communication. Thus, while it is expected that there would be some overlap in the cognitive skills required to produce initial statements and repairs, there may be some differences. Investigating a similar communicative skill to repairs, one study examined the relationship between executive functioning and children's ability to benefit from feedback to produce more effective subsequent messages. Wardlow and Heyman (2016) investigated the relationship between children's working memory skills and their ability to benefit from nonverbal feedback indicating they have been misunderstood. In this study, 5- to 7-year-olds completed a referential communication task, where they described pictures for an experimenter. During this task, half of the children received no feedback following an ambiguous message (the experimenter always chose the correct picture in this condition), and half the children received non-verbal feedback following ambiguous messages (i.e., the experimenter made a confused facial expression and chose a picture which matched the child's description, but was not the target). Children who received feedback during the referential communication task provided more effective messages on average across trials compared to those who received no feedback. Additionally, better working memory was associated with increased speaker effectiveness, but only for participants who received feedback during training trials. The authors concluded that children with better working memory were better able to remember the previous feedback they had received, and were better able to use this information to provide more effective messages following training. Although this study provides some evidence that working memory is involved in children's ability to use listener feedback to improve their ability as speakers, there are some limitations to these findings. In this study, children were not provided with the opportunity to repair their message once the listener indicated that a communication breakdown had occurred (rather their performance was examined on subsequent trials only). As such, it is unclear what role executive functioning plays in the process of children's modifying their initial messages following such feedback. Further it is unclear whether the role of executive functioning would apply to the late preschool ages and what whether other components of executive functioning, such as cognitive flexibility and inhibitory control, would play a role.

In conclusion, the current literature demonstrates a key role of executive functioning in children's production of referential statements and hints that executive functioning may play a role in communication repair (Coon et al., 1982; Volden 2004; Wardlow & Heyman, 2016). However, no empirical work has been dedicated to examining the cognitive skills underlying children's communicative repairs. As such, the relation between executive functioning and communication repair remains unclear. This is an important area for future research, since, as noted earlier, young children frequently fail to provide enough information for their listeners (e.g. Lloyd et al., 1998), requiring that they repair initial statements often. Further, receiving feedback from their listeners and subsequently repairing their messages may be one important way through which children learn to become effective speakers (see Matthews et al., 2007; 2012). Thus, identifying the cognitive skills which underlie repair could allow for early identification of children who may develop difficulties with communication. Moreover, research in this area could also be beneficial for informing treatments targeted to improve children's communication. For instance, practicing communication repair has been shown to improve children's effectiveness as speakers (Matthews et al., 2007; 2012), but it is unclear whether individual differences in EF skills would impact the degree to which this benefit is achieved.

Introduction

During everyday interactions, children often fail to provide enough information to successfully convey their intended message to listeners. Thus, children's ability to identify communication breakdowns and subsequently repair initial messages is an essential component of the development of effective communication. The present study investigated the degree to which 4- to 6-year-old children benefit from specific versus vague feedback that miscommunication has occurred for their repair strategies. It also examined whether stronger executive functioning played a facilitating role for children's ability to repair their statements following feedback from their listener.

Decades of research on referential communication has found that young children often provide ambiguous statements for their listeners (e.g. Glucksberg et al., 1966; Krauss & Glucksberg 1969; Lloyd, et al., 1998; Pechmann & Deutsch, 1982). For example, during a referential communication task requiring that a speaker describe a target object for a listener, a child might say, "the green triangle," even if the larger set of objects contained both a large and a small green triangle. While studies that have reduced the cognitive demands of the referential communication task (e.g., fewer objects) have attributed more success to preschool and early school-age children than early studies (e.g., Nadig & Sedivy, 2001; Nilsen & Graham, 2009), children's management of the task of producing effective referential statements shows a steady, but gradual improvement throughout the school-age years (Krauss & Glucksberg, 1969; Lloyd et al., 1998; Pechmann & Deutsch, 1982).

Children's difficulty in producing effective statements means that miscommunication during conversational exchanges is a frequent occurrence. Further, it means that children's ability to notice and repair communication breakdowns is critically important for effective communication. Children demonstrate attempts to repair their statements as early as infancy. One-year-old infants use pointing and vocalizations to repair messages that appear to be misunderstood by their listeners (Golinkof, 1986; Liszkowski et al., 2008). For example, when an adult fails to look at an object the infant is pointing at, the infant will continue pointing at it (Liszkowski et al., 2008). While young children *attempt* to repair their messages, there are mixed results as to the effectiveness of communication repair in preschool-aged children. For example, two-year-olds were found to use pointing to repair their messages following a request for clarification from an experimenter, even when pointing could not be used to uniquely identify a specific object (O'Neill & Topolovec, 2001), suggesting that at this age they lack the skills needed in order to account for the needs of the listener when repairing a statement. In contrast, several studies have found that preschool-aged children are able to effectively repair their statements following requests for clarification (albeit not completely consistently; Coon, et al., 1982; Deutsch & Pechmann, 1982; Nilsen & Mangal, 2013). For example, when children (ages 3, 6, and 9) requested objects from an experimenter and were asked for clarification following an ambiguous message (e.g. "which ball?"), they were able to effectively repair their message on the majority of trials (Deutsch & Pechmann, 1982).

The type of feedback provided by the listener appears to be important in determining the effectiveness of children's repair strategies. In a study by Coon and colleagues (1982), children completed a referential communication task in which they were provided with feedback when they produced ambiguous messages. This feedback varied in specificity, and in whether or not the experimenter showed the child the listener's incorrect object choice (i.e. an object that matched the child's description but was not the target). The least specific feedback involved the experimenter indicating the incorrect object that was chosen and saying, "Tell me whatever I need to know to pick the right one." For the most specific feedback, the experimenter said a variation of the following: "There were several red ones and I picked the wrong one. I picked a red circle." Children were most effective at repairing their messages (i.e. they were able to provide more descriptors to disambiguate the target from distractors) following specific feedback, or when shown the listener's incorrect object choice. Other studies have found similar effects of feedback type. That is, children often use the ineffective strategy of repeating their initially ambiguous statement following vague feedback (e.g. "what?"; Anselmi et al., 1986; Nilsen & Mangal, 2013; Wilcox & Webster, 1980), and modify their messages to include additional important elements following specific queries about their statements (Anselmi et al., 1986) or when shown the listener's incorrect object choice (Coon et al., 1982; Nilsen & Mangal, 2013).

The type of feedback provided to children also has an impact on children's subsequent messages. In two studies by Matthews and colleagues (2007; 2012) children (ages 2 to 4) provided referential statements for a listener and were provided with generic (e.g. Which girl?) or specific (e.g. Is it the girl dancing or the girl singing?") feedback following ambiguous messages. Children of all ages provided more effective statements on later trials following this training, and learned to do so more quickly following specific feedback. Being allowed the opportunity to repair messages seems to provide children with the richest training in that when this occurs subsequent messages are more effective relative to simply observing others provide and repair messages (Matthews et al., 2007). Other work similarly finds that children are able to learn to produce more effective messages when provided with feedback indicating they have been misunderstood (see Abbot-Smith et al., 2015; Lefebvre-Pinard et al., 1982; Robinson & Robinson, 1981; 1985; Wardlow & Heyman, 2016 for similar findings).

Executive functions, the cognitive skills that control and regulate other lower-level cognitive processes and goal-directed behaviour (Alvarez & Emory, 2006), are thought to support the *use* of information about a communicative partner's perspective for guiding communicative behaviours (Nilsen & Fecica, 2011). Executive functions consist of several components including the ability to hold in mind and mentally manipulate information (working memory), the ability to withhold a dominant response (inhibitory control) and the ability to think flexibly and switch one's way of thinking about a problem (cognitive flexibility). While there is currently no consensus as to the structure of executive functions in preschool-aged children (e.g. Müller & Kerns, 2015; Weibe et al., 2011), a working model consisting of the three components described previously was used for the current investigation.

Several studies have investigated the influence of individual differences in executive functioning on children's initial production of statements. Speakers' working memory and inhibitory control skills were found to be associated with their ability to tailor referential statements for their listener's needs (Nilsen et al., 2015; Wardlow, 2013). Executive functioning was also found to be associated with listeners' abilities to effectively account for a speaker's perspective while interpreting their referential statements. For instance, individuals with stronger working memory and inhibitory control have been found to be more likely to attend to the speaker's perspective when interpreting their messages (Brown-Schmidt, 2009; Lin et al., 2010; Nilsen & Graham, 2009; Wardlow, 2013).

The role of executive functioning in children's communication repairs has not been examined empirically. However, there is theoretical reason to see executive functioning as playing a key role. Volden (2004) proposed that communication repair involves three main steps: "(1) an ability to judge another person's state of knowledge; (2) a comparison of the listener's perceived state of knowledge with the speaker's original utterance and a subsequent determination about what components of the original message were inadequate; and (3) an adjustment to the speaker's utterance that is based on steps 1 and 2." Past research suggests that young children are somewhat capable of step 1: judging a listener's knowledge state (e.g. Nadig & Sedivy, 2002; Nilsen & Graham, 2011). Volden has suggested that steps 2 and 3 may involve working memory, as the child would be required to hold information in mind about their listener's perspective, the listener's feedback, and their own statement before producing a revised statement. Steps 2 and 3 may involve inhibition and cognitive flexibility as well. Inhibition may be needed to inhibit information about one's own perspective in order to account for the listener's perspective. Cognitive flexibility may be required in order to modify one's statement rather than repeating the original message.

Further, clinical populations which are impaired in executive functioning including those with autism (Ozonoff, 1995), epilepsy (Hernandez et al., 2002), and schizophrenia (Sullivan et al., 1994) show difficulties with this aspect of communication. Communication repair is impaired in individuals with autism and pervasive developmental disorder (Paul & Cohen, 1982; Volden, 2004). For example, Volden (2004) found that children with these disorders were more likely than typically developing children to respond to requests for clarification with an off-topic remark. Additionally, work by Caplan (1996; 2001) found that children with schizophrenia and epilepsy are impaired in self-initiated communication repair, which refers to when an individual notices a communication breakdown has occurred in the absence of receiving feedback, and modifies their message.

Moreover, studies showing that detailed feedback or showing the listener's incorrect object choice facilitates children's communication repair are consistent with the idea that executive functioning is involved in repair (Anselmi, et al., 1986; Coon et al., 1982; Nilsen & Mangal, 2013). Specific feedback or showing the listener's incorrect object choice may reduce the cognitive demands of communication repair (Coon et al., 1982). When provided with specific feedback or shown the listener's incorrect object choice in a referential communication task, the child only needs to compare their original message with the referents identified by the listener. When provided with vague feedback the child must compare his or her statement with all the possible referents in the array in order to determine what was lacking in the original message. Thus, detailed feedback could possibly reduce the amount of information the child needs to hold in working memory. In addition, detailed feedback may make the perspective of the listener more obvious, thereby making it easier to inhibit one's own perspective in order to take the listener's perspective into account. Detailed feedback may also reduce the demands on cognitive flexibility by making more salient which dimensions of the target object the listener is confused about and making the aspects of the object which a child needs to think flexibly about (i.e., that the object is both red and large, etc.) more obvious.

Although no previous work has directly examined the role of executive functioning in the act of repairing one's statements, a recent study investigated the role of working memory in children's ability to benefit from feedback indicating they have been misunderstood in order to produce more effective subsequent messages. Wardlow and Heyman (2016) asked 5- to 7-year-olds to describe pictures for an experimenter. During this task, children received either no feedback following an ambiguous message (the experimenter always picked the correct object) or received non-verbal feedback (i.e., the experimenter made a confused facial expression and chose a picture which matched the child's description, but was not the target). Children who received feedback during this training provided more effective subsequent messages, and among those who received feedback, children with better working memory provided more effective subsequent messages. The authors suggested that children with better working memory were better able to incorporate and remember the feedback they had received on subsequent trials.

Although this study provides some evidence that working memory may be involved in communication repair, children were not given the opportunity to repair their statements. The processes involved in repairing one's statement may differ from those involved in learning to provide more effective subsequent messages from previous feedback. This is because repairing statements involves responding to a situation in the moment and requires consideration of one's own original message as well as the listener's feedback. In contrast, benefitting from previous feedback to produce more effective messages appears to reflect learning about what constitutes effective communication, which can then be carried forward into subsequent acts of communication. Because of these potential differences, it is unclear what role executive functioning plays in the process of modifying one's message following feedback. Further, Wardlow and Heyman's study did not investigate the role of other executive functions, such as cognitive flexibility and working memory, in children's ability to improve their messages following feedback. It is also unclear whether these findings would apply to late preschool-aged children.

The existing literature highlights a key role of executive functioning in children's production of referential statements and suggests that executive functioning may also play a role in communication repair, a premise yet to be examined empirically.. While it may be the case that similar executive functioning skills are involved in both communication repair and the production of initial statements, there may be some differences given the added complexities of repair.

Addressing this gap in the literature, the goal of the present study was to examine the relationship between executive functioning and late preschool-aged children's ability to repair their messages following feedback indicating they have been misunderstood. Another goal of the study was to determine whether the role of executive functioning in repair differed depending on the type of feedback provided. That is, I wanted to determine if detailed feedback reduces the demands on executive functioning relative to vague feedback.

In the present study, 4-to 6-year-old children completed a referential communication task in which they described pictures to an experimenter. The stimuli were designed such that initial miscommunication was likely to occur. When the child provided an ambiguous message, the experimenter provided half of the participants with detailed feedback, which identified where the miscommunication occurred and half of the participants with vague feedback, which did not. Following this feedback, children were given the opportunity to repair their messages. Children also completed executive functioning tasks assessing their working memory, inhibitory control and cognitive flexibility.

It was predicted that children who received detailed feedback would provide more descriptors of the target than those who received vague feedback, which would be consistent with past research (e.g. Coon et al., 1982; Nilsen & Mangal, 2013). It was also anticipated that children with better executive functioning would provide more descriptors following feedback, although the degree to which each component of executive functioning would be beneficial for children's repairs was unclear. Thus, a goal of the present investigation was to explore the relationships between each component of executive functioning and children's repairs. Further, it was anticipated that the effect of executive functioning on repairs would be stronger for children who received vague feedback compared to those who received detailed feedback. Such a finding would be consistent with the premise that detailed feedback may reduce the cognitive demands of repair (Coon et al., 1982), since executive functioning would play a greater role in repair following vague feedback.

Method

Participants

Participants were 140 children between the ages of 4 and 6 (M_{age} = 5 years; *SD* = 6.6 months; 70 females), recruited from elementary schools in a mid-sized Canadian city.

During the communication task, participants completed filler trials (see procedure). These trials required participants to simply name the target picture (e.g. "grapes"). As this was intended to be a simple task and the ability to select the correct target is critical for completing the communication task, participants who provided an incorrect response (i.e. were unable to correctly identify the target) on 3 filler trials throughout the communication task were discontinued from the study and not included in analyses (*n* = 23)[1]. The majority of participants who were unable to complete the filler trials also appeared to have difficulty understanding the task instructions (e.g. they repeatedly named the incorrect targets across trials). Participants' data was also removed from analyses if their vocabulary score was not deemed sufficient to support the task (SD > 3 below the mean on the expressive vocabulary task; *n* = 1) or there were technical difficulties with video equipment which prohibited coding the data (*n* = 1). Thus, 25 participants were removed from the analyses in total, leaving *N* = 115 participants (M_{age} = 5 years; 57 females).

The majority of participants in the remaining sample were reported to have spoken English since birth (*n* = 108). Most participants also spoke primarily English in the home (*n* = 98), while several participants spoke a wide variety of other languages at home (*n* = 17), including Punjabi, Japanese and Russian.

Procedure

Participants were recruited from elementary schools in a mid-sized Canadian city. Participants' parents were provided with consent forms outlining the tasks involved in the study and given the opportunity to decide if they would like for their child to participate.

[1] The majority of participants in the study (77%) were able to identify the correct target on 100% of the filler trials.

Children whose parents provided consent were asked if they would like to participate in the study and were told they could choose to end participation in the study at any time. Participants who agreed to participate were individually administered tasks in a quiet room at their school during school hours. Participants completed tasks in a set order during one 40-minute session, a standard practice for looking at individual differences; i.e., the communication task was first, followed by the Red Dog – Blue Dog task, the Digit Span task, the Object Classification task and lastly the Picture Naming task.

Communication task. Children were tested by an experimenter and an adult confederate. The child and confederate sat across from one another, with a barrier between them to prevent them from seeing each other's picture cards. The experimenter sat at the side of the table, between the confederate and experimenter and directed the task (see Figure 1 for task layout). On each trial, the child was given a complete card depicting a scene containing several people, animals, or objects (see Figure 2; stimuli were modified from Nilsen & Mangal, 2013). The child and confederate were also both given copies of an incomplete card, which depicted the same scene as the other card, but had one person/animal/object missing. The missing feature was replaced with an empty circle to indicate that something was missing. Both the child and confederate were also given identical sets of small pictures. These pictures depicted objects, people and animals shown on the card as well as some pictures that were not present in the large card. Both the child and confederate had the same incomplete card and pictures on each trial.

The communication task consisted of 16 trials (2 practice trials, 6 test trials and 8 filler trials). At the beginning of the task, the experimenter placed the barrier between the confederate and child and explained that it would prevent them from seeing each other's scene cards and pictures. The experimenter also explained that the child and confederate had the same incomplete scene card and pictures, but that the confederate did not have the complete card. The experimenter showed the children the confederate's scene card and pictures on each trial to remind them of this. Following this, the children completed two practice trials. For the practice trials, children were asked to tell the confederate which picture she would need to make her incomplete scene card look the same as the child's complete scene card. To be successful, the child only needed to provide the target picture's object name (e.g. "shirt") in order to uniquely identify it for the confederate. During the practice trials, the experimenter also introduced and explained the purpose of a light to the child, which was used by the experimenter to indicate whether or not the confederate had chosen the correct target on each trial. When the confederate chose the correct target, the experimenter turned on the light in front of her. When the confederate picked the incorrect target, the experimenter did not turn on the light.

Following the practice trials, children were administered the test and filler trials. The stimuli for test and filler trials were presented in a counterbalanced order. On test trials, the pictures the child and confederate had to choose from contained the target, as well as two pictures that depicted the same object as the target but differed on one dimension, and six pictures of different objects. For example, on one trial where a red clown juggling balls was the target, the picture cards included this image as well as a blue clown juggling balls, and a red clown holding balloons (see Figure 2). Thus, in order to uniquely identify the correct target for the confederate, the child was required to provide two descriptors of the target (e.g. "the *red* clown *juggling balls*"). If the child successfully provided two descriptors of the target, the experimenter turned on the light and the confederate said, “The light turned on. I picked the right one.” If the child failed to provide two correct descriptors, the confederate always chose the wrong picture card and provided the child with feedback indicating that he/she had been misunderstood. The type of feedback varied between subjects. Participants received either *detailed* or *vague* feedback. Detailed feedback was modified depending on the participants’ initial response, and included a statement of misunderstanding as well as specific information about what was lacking in the child’s original statement. For example, if the target was a red clown juggling balls, and the child’s initial response was “the red clown”, the confederate would say, “I picked the wrong one. There are two red clowns and I don’t know which one you mean.” Vague feedback was the same regardless of the participant’s initial response and only included a statement of misunderstanding (i.e., “I picked the wrong one. I don’t know which one you mean.”).

Following feedback, the child was given approximately 10 seconds to repair their message. If the child did not respond in this time frame, or was unable to uniquely identify the target following feedback, the experimenter said “Actually, let’s try another one,” and switched the scene cards to move on to the next trial. If the child was able to uniquely identify the target following feedback, the experimenter turned on the light and the confederate indicated that she chose the correct card by saying “The light turned on. I picked the right one.”

The communication task also included filler trials, which were included to vary the number of descriptors required on each trial, and thereby required that participants attend closely to the object options provided, as well as reducing the possibility of participants adopting a strategy of providing many descriptors each time and reaching ceiling on the task. Filler trials (n = 8) were interspersed among the test trials in a pseudorandom order. On filler trials, the picture cards the child and confederate had to choose from contained the target, as well several pictures that were not similar to the target. Since the picture options were not similar, the child was only required to say the object name (e.g. “grapes”) to uniquely identify the target for the confederate. When the child provided the correct object name, the confederate picked up the correct picture card and the experimenter turned on the light. The confederate then told the child she chose the correct card and a new trial was started. When the child provided the incorrect object name, the experimenter said “Actually, let’s try another one” and moved on to the next trial. No feedback was provided following an inadequate response on filler trials.

Following completion of the trials, participants were asked if the confederate could see their picture cards when they were on the child’s side of the table, and were blocked by the barrier. This question was asked to 77% of participants, as it was implemented after the study had already begun to be run. The question was intended as a manipulation check to see if participants understood that the confederate could not see their cards during the task. After this question was asked, participants were administered the executive functioning tasks.

Coding. Children’s responses were coded by a research assistant blind to the research hypotheses. Participants’ responses were coded for the number of descriptors provided in the first response, the number of new descriptors provided following feedback, whether or not they repeated a previous response, and behavioural responses, such as pointing.

The number of descriptors referred to those descriptors which disambiguated the target picture from distractor pictures. For example, if a participant said, "the *red* clown", his or her response would be coded as containing one descriptor. Descriptors which did not disambiguate the target picture were not included (e.g., "the clown with black shoes" would be coded as no descriptors since all clowns in the array of pictures were wearing black shoes and thus "black shoes" does not disambiguate the target). New descriptors in the second response were coded as the number of informative descriptors provided in the second response which were not provided during the first response. Repetitions were coded as statements in the second response in which the participant repeated their initial response and did not provide any additional information. Participants were coded as pointing to the picture cards if they pointed to one of the picture options in front of them, or pointed to the target picture on the complete scene card. This latter response would be considered an ineffective strategy given that the barrier prohibited the confederate from seeing what the participant was pointing towards. Several other communicative responses[2] and behaviours, such as describing the incorrect target and holding up the card above the barrier were also coded.

A second research assistant coded the behaviours of 32 (25% of the total sample) randomly chosen participants to ensure reliability in coding. The interrater reliability of the number of descriptors provided in participants' initial descriptors was found to be near-perfect, $ICC(181) = 1.00$, $p < .001$. The inter-rater reliability of the number of new descriptors provided by participants following feedback was similarly high, $ICC(138) =$

[2] Other behaviours were coded as well, including whether or not participants used the spatial location of the target object in their description, whether they provided irrelevant or incorrect descriptors that did not help to disambiguate the target picture from distractors, and whether they described the incorrect target. These behaviours were not included in subsequent analyses as they occurred infrequently (i.e. on less than 6% of trials).

.97, $p < .001$. Reliability was also assessed for coding repetitions, $ICC(138) = .53$, $p < .001$, pointing to cards during the first response, $ICC(181) = .81$, $p < .001$, and pointing to cards during the second response, $ICC(138) = .77$, $p < .001$. The inter-rater reliability of coding repetitions was somewhat low. However it should be noted that the incidence of repetitions was low, occurring on approximately 13% of trials.

Working memory. Following the communication task, children completed the Digit Span subtest from the Wechsler Intelligence Scale for Children - Fourth Edition (WISC-IV; Wechsler, 2003) as a measure of verbal working memory. Span tasks such as this have been found to fall on a working memory factor in factor-analytic studies (Fournier-Vicente, Larigauderie, & Gaonac'h, 2008; Pennington, 1997). This task was administered in a standardized manner as indicated in the WISC-IV manual. Participants first completed the Digit Span Forwards task wherein the experimenter read a series of digits then participants were asked to repeat the digits in the same order. Following this, participants completed the Digit Span Backwards subtest which required that they repeat the digit string in a backwards order. The Digit Span Forwards and Digit Span Backwards tasks each consisted of 8 items, with 2 trials per item. Each trial consisted of a string of digits, with the length of the strings of digits increasing across items. When a child provided the incorrect response on both trials of an item, the task was discontinued. Participants received one point for each correct response per trial. A total digit span score, used in the analyses, was calculated by adding the Digit Span Forwards and Digit Span Backwards scores. Possible scores ranged from 0 to 32.

Inhibitory control. The Red Dog – Blue Dog task was used to assess inhibitory control. This Stroop-like task (from Nilsen & Graham, 2009; modified from Beveridge, Jarrold, & Pettit, 2002) has been used in previous studies on a sample of 4- to 5-year-olds (Nilsen & Graham, 2009) and on a sample of 6- and 8-year-olds (Beveridge et al., 2002). Stroop tasks are thought to be a measure of inhibitory control (Stroop, 1935; Wright, Waterman, Precott, & Murdoch-Eaton, 2003), and have been found to load onto factors of inhibition in factor-analytic studies (Miyake et al., 2000).

Participants were shown a card depicting a red dog, which they were told was named “Blue” and a card depicting a blue dog, which they were told was named “Red”. Children first completed two practice trials, and were given corrective feedback if they provided the wrong name. Following this, they were shown 28 cards depicting red and blue dogs, one at a time, at a consistent rate of approximately one card per second. They were asked to say each dog’s name out loud as the cards were presented. Children did not receive feedback following their responses. To be accurate, participants were required to inhibit their natural response of saying the colour of the dog. Participants received a total score out of 28, which reflected the number of cards they correctly named initially, as well as the number of cards on which they self-corrected their response. Possible scores on this task ranged from 0 to 28.

Cognitive flexibility. Participants completed the Object Classification task for Children (OCTC; Smidts, Jacobs, & Anderson, 2004) as a measure of cognitive flexibility. This is a sorting task similar to the Concept Generation Test for Children (CGT–C; Jacobs, Anderson, & Harvey, 2001), but was developed for use with children between the ages of 3 and 7 years old (Smidts et al., 2004). Children completed a practice trial to help them become familiar with how they should sort the test objects. During the practice trial, they were provided with four toys that consisted of two sets of identical toys (i.e. two plastic ducks and two plastic turtles) and were asked to group the toys that were the same together. If a child did not do this correctly, they were provided with corrective feedback (i.e. "So can you tell me which toys are the same?... Now put these toys on this side of the table and put the other two toys on that side of the table."). All children were able to correctly sort the practice objects following this corrective feedback. They were then provided with six test objects: a small yellow plane, small red plane, large red plane, large red car, large yellow car, and a small yellow car. Participants were then asked to sort these toys into two groups, with something being the same about the toys in each group. The toys could be successfully sorted based on size, colour or function. If a child was unable to determine a way to sort the objects, two toys were removed and the task proceeded with four objects. After the children had sorted the toys, the experimenter asked them what was the same about the toys in each group they had created. Following this, the children were asked to sort the toys again, but were told, "this time something else has to be the same about the toys". Once they sorted the toys a second time, they were again asked to describe what was the same about the toys in each group. This procedure was then repeated a third time.

Participants received three points for each correct sorting, and received an additional point for correctly labelling their sorting criteria, resulting in a total of 12 possible points. If children were unable to sort the objects in all three possible ways, the experimenter grouped the toys in the fashions that were missed, and asked the child what was the same about the toys in each group she had created. Children received two points for correctly labelling the sorting criteria for each sort. If children were unable to correctly name the sorting criteria using this procedure, the experimenter then asked them to group the objects based on the criteria they had missed (e.g., "Can you put all the red ones on this side of the table, and all the yellow ones on that side of the table?). Participants received one point for each correct sorting per instruction provided by the experimenter. Participants' total numbers of points received were pooled across the conditions described above. Possible scores on this task ranged from 0 to 12.

Expressive vocabulary. Lastly, participants' expressive vocabulary was assessed using the Picture Naming task from the Wechsler Preschool and Primary Scale of Intelligence – Third Edition (WPPSI-III; Wechsler, 2002) in order to determine that participants had adequate expressive vocabulary skills for the task and for this factor to be controlled in subsequent analyses. The task was administered in a standardized fashion based on the procedure outlined in the WPPSI-III manual. Participants were shown a series of 30 pictures from a booklet and were asked to name them. Difficulty increased with each subsequent item. When children provided an incorrect response on 5 consecutive items, they were discontinued from the task. Children's raw scores, which had a possible range from 0 to 30, were used for analyses.

Results

Preliminary Analyses

As mentioned previously, one participant's data was removed from analyses as his expressive vocabulary score was a statistical outlier. Outliers for expressive vocabulary were handled in this way because children without adequately developed expressive vocabulary would be expected to have difficulty completing the communication task generally. Outliers for other variables were Winsorized to be within 3 standard deviations of the mean (as per Tabachnick & Fidell, 2007; Red Dog – Blue

Dog task [$n = 4$]). The standardized residuals of all regression analyses showed normal distributions.

There was no significant difference between the detailed and vague feedback conditions in participants' age, gender or expressive vocabulary ($ps > .23$). Male participants in the study ($M_{\text{age}} = 5.21$, $SD = .49$) were significantly older than female participants ($M_{\text{age}} = 4.92$, $SD = .55$), $t(113) = 3.07$, $p = .003$, $d = .56$. Males also had significantly higher expressive vocabulary and a greater tendency to respond after receiving feedback; however, when age was controlled for as a covariate, these differences were no longer statistically significant. As such, age but not gender was controlled for in subsequent analyses.

Following the communication task, a subsection of participants were asked whether the confederate could see their picture cards when they were on the child's side of the table, and were blocked by the barrier. Of these participants, 81% responded correctly that the confederate could not see their cards. Thus, the majority of participants understood that the confederate could not see their cards behind the barrier. Participants who responded incorrectly that the confederate could see their cards ($n = 17$) did not differ significantly in the level of detail provided in their initial responses from participants who correctly answered the question ($n = 69$; $p = .22$); however, they provided less detail following feedback compared to participants who answered the question correctly, $t(84) = 2.41$, $p = .02$, $d = .69$[3].

[3] When these participants were removed from analyses, the results of the study did not change, with the exception that cognitive flexibility was a marginally significant predictor of participants' initial responses ($p = .07$) as opposed to being a significant predictor when all participants were included ($p = .03$).

Executive Functioning Tasks

Children's mean performance on the executive functioning tasks was as follows: Digit Span: M = 8.05, SD = 3.08; Red Dog - Blue Dog: M = 22.31, SD = 5.82; Object Classification Task : M = 8.10, SD = 2.15. Correlations between measures of executive functioning, age, and expressive vocabulary are shown in Table 1. Children's working memory and cognitive flexibility were found to improve with age and increasing vocabulary skills, whereas there was no significant correlation between age or vocabulary and inhibitory control. Inspection of the data revealed a negatively skewed distribution for the Red Dog - Blue Dog task (40% of participants had a score of 26 or higher, with the maximum possible score being 28). Thus, a ceiling effect for the Red Dog – Blue Dog task may explain the lack of association between performance on this task, age, and vocabulary.

Initial Responses

Although the main focus of the study was to examine repairs, children's initial responses were first examined. As was intended, on the majority of trials participants failed to provide enough information within their initial responses to uniquely identify the target picture for the confederate. More specifically, the mean number of descriptors provided in the first response (M = .72, SD = .57) was substantially lower than the number of descriptors required to uniquely identify the target (2 descriptors). Participants were able to uniquely identify the target for the confederate during their first response on 21% of trials.

Participants' initial descriptions of the target improved across trials (first trial: M = 0.46, SD = .70; second trial: M = 0.58, SD = .77; third trial: M = 0.85, SD = .76; fourth trial: $M = 0.90$, $SD = .81$; fifth trial: $M = 0.82$, $SD = .85$; sixth trial: $M = 0.83$, $SD = .77$), $F(5, 530) = 9.63$, $p < .001$, $\eta_p^2 = .08$. On average across trials, participants in the detailed condition were not found to provide significantly more descriptors ($M = .77$, $SD = .60$) compared to those in the vague condition ($M = .68$, $SD = .53$), $p = .34$ (see Table 2), and there was no interaction between test trial and feedback type, $p = .77$ (see Table 3). However, participants in the vague condition ($M = .15$, $SD = .24$) pointed to the target card more often than participants in the detailed condition ($M = .06$, $SD = .13$), $t(113) = 2.69$, $p = .008$, $d = .52$. The frequency of other behaviours, such as holding up the target card to show the confederate, did not differ across feedback conditions, $ps > .48$.

Impact of executive functions on children's initial responses.

Correlations between children's executive functioning skills and their performance on the communication task are shown in Table 4. The relations between each of the three components of executive functions and children's initial descriptions of target pictures were assessed using hierarchical regression. As the executive functioning tasks were correlated, three separate regressions were conducted for each of the three executive functioning components in order to ensure that the shared variance between these measures did not impact the findings. The use of separate regressions allowed for investigation into the impact of each executive functioning component. The dependent variable for each regression was the average number of descriptors provided in participants' initial responses across trials. To control for age and expressive vocabulary, these variables were entered into each regression as a first step. Age and expressive vocabulary alone predicted 17% of the variance in the average number of descriptors provided across trials and were both significant predictors of the number of descriptors provided (age: β = .21, $p = .02$; expressive vocabulary: β = .28, $p = .003$). This model was statistically significant, $F(2,108) = 10.81$, $p < .001$.

The interactions between each component of executive functioning and feedback condition were also assessed using multiple regression. Age and expressive vocabulary were entered in the first step of each regression. Each component of executive functioning and feedback type were entered in the second step. Lastly, the interaction term for each component of executive functioning with feedback type was included in the third step. No statistically significant interactions were found between working memory (working memory X feedback type: β =.03, $p = .78$), inhibitory control (inhibitory control X feedback type: β = .23, $p = .37$), or cognitive flexibility (cognitive flexibility X feedback type: β = .18, $p = .16$) with feedback type. As such, interaction terms were not included in subsequent analyses.

Working memory. When working memory was entered into the regression as the second step, a 6% increase in the variance of descriptors provided was explained by the model. This change in R^2 was significant, $\Delta F(1,107) = 7.68$, $p = .007$. Together, age, expressive vocabulary and working memory accounted for 22% of the variance in descriptors provided. The model was statistically significant, $F(3,107) = 10.21$, $p < .001$. When examining the regression weights of the predictors, working memory (β = .26, p = .007) and expressive vocabulary (β = .19, $p = .049$) were significant predictors, while age (β = .17, $p = .08$) was no longer a significant predictor.

Inhibitory control. When inhibitory control was entered into the second step of the regression, an additional 3% in the variance of descriptors provided was explained by the model. This change in R^2 was not statistically significant ($p = .50$). Age, expressive vocabulary and inhibitory control together predicted 17% of the variance in the number of descriptors provided. The overall model was statistically significant, $F(3,106) = 7.39$, $p < .001$. When examining the regression weights of the predictor variables, age ($\beta = .22$, $p = .02$) and expressive vocabulary ($\beta = .27$, $p = .005$) were significant predictors of children's initial descriptors provided, but inhibitory control was not ($\beta = .061$, $p = .50$).

Cognitive flexibility. When cognitive flexibility was entered into the second step of the regression, an additional 4% in the variance of descriptors provided was explained by the model. This change in R^2 was statistically significant, $\Delta F(1,107) = 4.83$, $p = .03$. Together, cognitive flexibility, age and expressive vocabulary accounted for 20% of the variance in descriptors provided. The overall model was statistically significant, $F(3,107) = 9.08$, $p < .001$. When examining the regression weights of the predictor variables, cognitive flexibility ($\beta = .20$, $p = .03$) and expressive vocabulary ($\beta = .23$, $p = .005$) were significant predictors of children's initial descriptors provided, but age was not ($\beta = .17$, $p = .07$).

Responses Following Feedback

After receiving feedback, participants provided, on average, less than one new descriptor on each trial ($M = .57$; $SD = .48$). On trials where the participant did not uniquely identify the target during the first trial and thus feedback was provided, participants were able to uniquely identify the target with their second response on 22% of trials. Children partially repaired their messages on 21% of trials, meaning they provided some new information following feedback, but not enough to uniquely identify the target. Participants provided no response after receiving feedback on 27% of trials and used ineffective repair strategies such as repeating themselves or pointing to the target on 30% of trials. Since feedback was only provided on trials where children did not uniquely identify the target during their first attempt, the majority of participants did not receive feedback on every trial. Thus, analyses on the effect of trial for repairs only included a subset of the sample. There was no significant effect of trial, meaning participants who received feedback on every trial did not provide more descriptors on subsequent test trials, $p = .37$. There was also no interaction between feedback type and test trial, $p = .61$.

As the main effect of the omnibus ANOVA would only include participants who had provided repair statements for all trials, the comparison between conditions was assessed through t-tests, with the average number of new descriptors provided across trials as the dependent variable. Participants who received detailed feedback ($M = .69$; $SD = .49$) provided significantly more new descriptors following feedback than participants in the vague condition ($M = .44$; $SD = .44$), $t(112) = 2.83$, $p = .006$, $d = 0.54$. Participants provided with detailed feedback were also less likely ($M = .10$; $SD = .19$) than those provided with vague feedback ($M = .24$; $SD = .30$) to repeat their initial response following feedback, $t(112) = 2.95$, $p = .004$, $d = 0.57$. The frequency of other behaviours in response to feedback did not differ across feedback conditions, *p*s > .11.

Impact of executive functions on children's repairs.

Correlations between children's executive functioning skills and their repairs are shown in Table 4. The relations between each of the three components of executive functions and children's descriptions of target pictures following feedback were assessed using hierarchical regression. Three separate regressions were conducted for each of the three executive functioning components. The dependent variable for each regression was the average number of new descriptors of the target picture provided across trials. To control for participants' age and expressive vocabulary, these variables were entered into each regression as a first step. Age and expressive vocabulary alone predicted 11% of the variance in the average number of new descriptors provided across trials, and together were statistically significant, $F(2,107) = 6.45$, $p = .002$. When individual predictors were examined, expressive vocabulary ($\beta = .25$, $p = .01$) was shown to predict the number of new descriptors provided, while age did not (age: $\beta = .14$, $p = .14$).

The interactions between each component of executive functioning and feedback condition were also assessed using multiple regression. These analyses were conducted using the same procedure discussed previously, with the exception that the dependent variable was the number of new descriptors provided during the second response. No statistically significant interactions were found between working memory (working memory X feedback type: $\beta = -.14$, $p = .26$), inhibitory control[4] (inhibitory control X feedback type: $\beta = -.44$, $p = .08$), or cognitive flexibility (cognitive flexibility X feedback type: $\beta = -.15$, $p = .23$), with feedback type. As such, interaction terms were not included in subsequent analyses.

Working memory. When working memory was entered into the regression as the second step, a 1% increase in the variance of the number of new descriptors provided was explained by the model. This change in R^2 was not significant, ($p = .33$). Together, age,

[4] Additional detail is provided for this marginally significant finding: When inhibitory control and feedback type were entered in the second step, the overall model was statistically significant, $F(4,104) = 4.67$, $p = .002$. When the interaction term of inhibitory control with feedback type was added in the third step, an additional 2% in the variance of number of new descriptors was explained by the model. This change in R^2 was marginally significant, $\Delta F(1,103) = 3.06$, $p = .08$, and yielded a marginally significant interaction term ($\beta = -.44$, $p = .08$). The interaction was such that the relation between inhibitory control and the number of new descriptors provided following feedback was weaker in the detailed condition ($r = -.10$, $p = .48$) than the vague condition ($r = .23$, $p = .09$).

expressive vocabulary and working memory accounted for 12% of the variance in descriptors provided. The model was statistically significant, $F(3,106) = 4.62$, $p = .004$. When examining the regression weights of the predictors, expressive vocabulary ($\beta = .22$, $p = .04$) was a significant predictor of descriptors provided, while age ($\beta = .13$, $p = .21$) and working memory ($\beta = .10$, $p = .33$) were not significant predictors.

Inhibitory control. When inhibitory control was entered into the second step of the regression, no additional variance in the number of new descriptors provided was explained by the model. The overall model remained statistically significant, $F(3,106) = 7.39$, $p < .001$. Age ($\beta = .22$, $p = .02$) and expressive vocabulary ($\beta = .27$, $p = .005$) were significant predictors of children's initial descriptors provided, but inhibitory control was not ($\beta = .061$, $p = .50$).

Cognitive flexibility. When cognitive flexibility was entered into the second step of the regression, an additional 4% of the variance in the number of new descriptors provided was explained by the model, with a statistically significant change in R^2, $\Delta F(1,106) = 4.85$, $p = .03$. The overall model was statistically significant, $F(3,106) = 6.07$, $p = .001$ with cognitive flexibility ($\beta = .21$, $p = .03$) and expressive vocabulary ($\beta = .20$, $p = .049$) significantly predicting children's new descriptors provided, but not age ($\beta = .10$, $p = .31$).

Responses following feedback controlling for first responses.

One challenge with analyzing the data for participants' responses following feedback is that the number of new descriptors that can possibly be added is dependent on how many descriptors were provided during children's initial responses. That is, as each target picture has two potential associated descriptors, when one descriptor is provided during children's initial responses, there is less room for improvement during the child's second response (relative to when no descriptors are provided). This issue makes analysis of the relations between executive functions and communication repair difficult. In particular, since working memory and cognitive flexibility are associated with children's initial responses, the possibility of these executive functions associating with children's second responses may be limited. To manage this, the data were also analyzed controlling for the number of descriptors provided in children's first response. Specifically, the data were analyzed separately for trials where children provided no descriptors in their initial response.

Using this approach, data were examined in the same manner that was described in previous sections, with the exception that the dependent variable for each regression was the average number of new descriptors of the target picture provided across trials *when no descriptors were provided during the initial response*. Results were consistent with previous analyses. That is, working memory and inhibitory control were not significant predictors of the number of new descriptors provided in children's second responses, whereas cognitive flexibility was a significant predictor. In particular, this result demonstrates that the previous finding where working memory did not relate to children's repairs was likely not attributable to a restricted range in the number of descriptors provided in the second response.

Discussion

The ability to repair one's message following miscommunication reflects an important aspect of communication. Indeed, without such a skill a listener would be left mistaken or unclear about the actual communicative intent. The present findings illustrate the degree to which this skill is impacted by both the type of the feedback provided by the listener as well as the executive skills of the speaker.

While the main focus of the study was on children's repair strategies, the results also provide insight into the skills required for initial attempts to communicate one's referential intention. Children's initial attempts to describe the target for the confederate will be discussed first, with their ability to repair statements following feedback discussed next.

The vast majority of participants provided ambiguous statements initially. Children's difficulty with including all the essential details necessary to uniquely identify an object for a listener was anticipated as it is consistent with previous work showing that children between the ages of 4 and 5 tend to perform poorly on referential communication tasks (e.g. Glucksberg et al., 1966; Krauss & Glucksberg 1969; Lloyd, et al., 1998; Pechmann & Deutsch, 1982). Notably, in the present study children's initial referential statements improved across trials, that is, subsequent trials included more relevant information, supporting the premise that children are able to learn to provide more effective statements following feedback indicating that they have been misunderstood (Abbot-Smith et al., 2015; Lefebvre-Pinard et al., 1982; Matthews 2007; 2012; Robinson & Robinson, 1981; 1985; Wardlow & Heyman, 2016).

The results of past studies suggest that children may fail to include essential information during referential communication due to the cognitive demands associated with managing this task. For example, compared to classic referential communication tasks, five-year-olds were able to perform better on a task designed by Nadig and Sedivy (2002), in which the cognitive demands associated with communication were reduced (see Nilsen & Graham, 2009). The present findings build on this notion by demonstrating that children with better executive functioning, specifically stronger working memory and cognitive flexibility, were found to provide more effective initial descriptions of target pictures for a listener (even when controlling for children's age and verbal skills).

With respect to working memory, individuals with larger working memory capacities may be better able to hold features of the target object in mind, and compare these features with the surrounding distractors, thereby producing more effective statements (as suggested by Wardlow, 2013). It may also be the case that the children with larger working memory capacities were better able to incorporate and remember the responses from the listener to produce more effective subsequent referential statements across the trials (as per Wardlow & Heyman, 2016). The role of working memory in children's ability to produce effective statements in the present study is consistent with the findings of past studies. Nilsen and colleagues (2015) found that 9- to 12-year-old children with better working memory provided more effective descriptions of objects in a referential communication task (however, participants with varying attention deficit hyperactivity disorder traits were recruited for this study). Reflecting some consistency in findings beyond childhood, Wardlow (2013) found that adults with stronger working memory were better able to account for which objects were visible and which were occluded from the listener's view when producing referential statements. The findings of the current study extend these findings to a typically developing sample of late-preschool aged children. Thus, while it may be the case that in some domains of communication executive functioning has a varying role depending on the developmental stage (e.g., Best et al., 2009; Gillis & Nilsen, 2014; Hughes & Ensor, 2007; Senn, Espy, & Kaufmann, 2004), it appears that working memory plays a continued role from preschool-age to adulthood.

However, the results of the present study differ from the findings of Nilsen & Graham (2009), who did not find a significant relationship between children's working memory and their effectiveness as speakers once age and verbal skills were controlled. This difference may be attributable to differences in the responses of the listener to children's statements. In Nilsen & Graham's study, the listener always chose the correct object, regardless of the child's statement, whereas in the present study the listener chose the wrong object in response to an ambiguous message from the child and provided the child with feedback. Thus, in the previous study, children may have 'learned' through the trials that the effectiveness of their statements did not matter to the outcome, and thus, stopped challenging themselves to include the relevant information. Indeed, Wardlow and Heyman (2016) found that the relationship between working memory and children's effectiveness as speakers was influenced by the listener's response to children's statements. Specifically, they found that working memory was only associated with children's effectiveness as speakers following trials where children received non-verbal feedback indicating they had been misunderstood. A significant relationship between working memory and speaker skills was not found for children who did not receive this feedback (though, it should be noted that the strength of the relationship between working memory and performance between the two feedback conditions did not significantly differ from each other).

Children with better cognitive flexibility also were found to produce more effective referential statements. Such a finding has not been demonstrated previously (e.g., Nilsen & Graham, 2009); however, work by Gillis and Nilsen (2014) found that children with stronger cognitive flexibility were better able to detect communicative ambiguity. Thus, it appears that children with stronger cognitive flexibility may be better able to notice the various dimensions of an object (e.g. notice that a red clown is also juggling balls), and can use this information to describe an object in a way that differentiates it from distractor objects.

Consistent with previous work examining children's production of statements (e.g., Nilsen & Graham, 2009; Nilsen et al., 2015), inhibitory control was not found to relate to children's effectiveness as speakers. However, studies examining the performance of adults have shown different findings. Wardlow (2013) found that adults with better inhibitory control were better able to account for which objects their listener could and could not see while producing referential statements. A number of differences between the present study and Wardlow's study could explain the discrepancies in these findings. Beyond the difference in participants' age and type of inhibitory task used, the communication task used in Wardlow's study required the speaker to attend to the perspective of the listener, since some objects were mutually visible to both the listener and speaker, whereas some were obscured from the listener's view (unlike the present study where perspective was not manipulated in that both the speaker and listener were able to see the same set of pictures). Wardlow's setup would likely place a greater load on inhibitory control, in that participants may have needed to inhibit their own perspective to a greater extent in order to take the listener's perspective into account. Indeed, in tasks manipulating perspective, preschoolers' inhibitory control relates to their communicative performance, albeit during comprehension rather than production (Nilsen

& Graham, 2009; 2012). However, it is also possible that this null finding is attributable to the negatively skewed distribution of children's scores on the inhibitory control task in the present study, which will be discussed further.

Turning to the main focus of the present study, while the majority of children attempted to provide a repair, they were relatively ineffective at completely repairing their messages in response to feedback. Children who provided ambiguous messages during their initial attempt were able to uniquely identify the target for the listener following feedback on only 22% of trials. Further, children partially repaired their messages on 21% of trials by providing some new information following feedback, but not enough to completely identify the target. Children used ineffective repair strategies such as pointing or repeating themselves on 30% of trials. Thus, most children attempted to repair their statements, but often did so ineffectively.

Feedback type was found to influence children's repair strategy, as has been shown in past studies (Anselmi et al., 1986; Coon et al., 1982; Nilsen & Mangal, 2013; Wilcox & Webster, 1980). Children who received detailed feedback following an ambiguous message provided more new descriptors of the target picture following feedback than children who received vague feedback. Replicating past work, children who received vague feedback were also more likely to repeat their original messages (Anselmi et al., 1986; Nilsen & Mangal, 2013; Wilcox & Webster, 1980). Children may resort to this strategy when they are unsure about what specific component of their statement was misunderstood by the listener. Further, children may interpret vague feedback to mean that the listener did not hear their initial statement properly.

The effectiveness of children's repairs in the present study was somewhat less than reported elsewhere. For example, in Deutsch and Pechmann's (1982) study, even the youngest age group (3-year-olds) was able to successfully repair their messages following feedback on 89% of trials. The type of feedback provided by the listener may account for this difference. In Deutsch and Pechmann's study, feedback consisted of questions (e.g. "which ball?"), whereas in the present study, feedback consisted of statements (e.g. "I don't know which one you mean."). As a result, participants were less directed as to what to do in the present study and may have not been prompted enough to provide a repair (e.g., there was no response to feedback on 27% of trials). A comparison of the present work with that of Deutsch and Pechmann's highlights the key role that feedback plays in the attempts and success of children's repairs.

The primary goal of the present work was to investigate whether children's executive functioning influenced their ability to repair messages. Researchers have hypothesized that executive functioning may facilitate children's communication repair. For example, Volden (2004) suggested that working memory may be involved in communication repair, since in order to repair their messages children would be required to hold information about their listener's perspective and their own initial statement in mind while formulating a repair statement. However, working memory did not predict repairs in the present study. Rather, in the present study, when children's age and verbal skills were controlled, cognitive flexibility emerged as a significant predictor of children's ability to repair their statements. Specifically, children with stronger cognitive flexibility provided more new descriptors of the target following feedback indicating they have been misunderstood. This novel finding is consistent with past work showing cognitive flexibility is important for children’s ability to detect communicative ambiguity (Gillis & Nilsen, 2014). Similar to how cognitive flexibility could facilitate children’s ability to produce effective initial statements (as discussed above), the act of seeing objects’ dimensions flexibly could also aid repairs. That is, when children are able to flexibly view different aspects of objects they may be better able to see what additional dimensions are important to describe. For example, in Figure 2, the target is not only a red clown; it is also a juggling clown. Such flexibility could allow children to better detect when ambiguity has occurred (as per Gillis & Nilsen, 2014) and know what additional information is important to provide to repair such ambiguity.

It was expected that, consistent with Volden’s (2004) predictions, working memory would be beneficial for children’s repairs given that this skill would allow children to hold in mind information pertaining to their listener’s perspective and their own initial statement while formulating a repair. However, results did not support this notion: working memory was not associated with children’s ability to repair their messages once age and verbal skills were controlled. Instead, working memory appears to play a role in children’s production of initial responses and not their repairs. This may be because when producing initial statements, children are required to hold a greater amount of information in mind, as they would need to compare the full set of objects in the array to produce an initial statement. During repairs, children would need to compare a smaller number of objects as in most cases they would have provided a response during their initial response which is close to the correct target. Thus, while a certain level of working memory capacity would almost certainly be required for effective communication repair, it is possible that additional working memory capacity beyond this level does not further contribute to children's ability to repair messages. In addition, while it was thought that inhibitory control may allow children to inhibit their own perspective in order to take their listener's perspective into account, results did not support this notion. Rather, consistent with previous findings failing to find a relationship between inhibitory control and the production of referential statements (Nilsen et al., 2015), there was no significant relationship between children's inhibitory control skills and repairs. It may be that the role of inhibitory control is more relevant for children's interpretation of referential statements as opposed to production (e.g., Nilsen & Graham, 2009). It is also possible, as previously mentioned, that the negatively skewed distribution of the inhibitory control task scores in the present study masked any potential associations between inhibitory control and other variables.

The present work allowed for an examination into whether there is a differential role of executive functioning depending on the type of feedback provided to a child. The hypothesis that children's executive functioning skills would be more relevant to successful repairs in a context where the feedback is vague as opposed to detailed (drawing from Coon et al.'s [1982] premise that cognitive demands are reduced by way of detailed feedback), was not supported in the current data. Rather, it was found that the magnitude of the relation between each component of executive functioning and children's repairs did not differ significantly across the feedback conditions. Thus, while it appears that detailed feedback may not have reduced the demands on executive functioning, it may have facilitated children's communication repair through some other means. For example, it is possible that detailed feedback made it clearer to children that their message was ambiguous, and needed to be modified rather than repeated. It is also possible that although the magnitude of the relation between executive functioning and children's repairs did not differ across conditions, the specific role that executive functioning (more specifically, cognitive flexibility) played in each condition may have been different. For example, following vague feedback, cognitive flexibility may have allowed for children to make comparisons between the properties of the target and distractor objects in order to determine what was lacking in their original statement. Following detailed feedback, cognitive flexibility may have allowed children to use the information provided by the listener about where miscommunication arose in order to determine what was lacking in their original statement, and what dimension of the target needed to be described.

Knowledge of which cognitive skills are involved in late preschool-aged children's communication repair could help with early identification of children who will eventually develop difficulties with communication skills, thereby allowing for early intervention. Additionally, the present findings suggest possible targets for interventions intended to improve children's referential communicative skills. Since executive functioning was found to play a role in children's effectiveness as speakers, improving children's executive functioning skills may aid their communication skills as well. Previous work has found that working memory training has been effective for children (Bergman-Nutley et al., 2011; Thorell, Lindqvist, Bergman-Nutley, Bohlin & Klingberg, 2009; see Melby-Lervåg & Hulme, 2013 for a review), and shows some evidence of generalizing to other areas of functioning (Roberts et al., 2011). However, no studies, to our knowledge, have investigated the efficacy of cognitive flexibility training. Moreover, it would be of interest for future research to investigate whether executive functioning training would generalize to children's communicative skills.

The findings of the present study may also inform interventions targeted to improve children's effectiveness as speakers. Past research has shown that children's effectiveness as speakers can improve through receiving feedback and being given the opportunity to repair their messages (e.g. Matthews et al., 2007; 2012). The present investigation provides further evidence that providing specific feedback can facilitate children's communication repair (as in Coon et al., 1982; Matthews et al., 2007), though more work is needed to determine how longstanding such a benefit may be. Matthews and colleagues (2007) provided children with three training sessions over three days, and found this led to children providing more effective messages during a post-test between one and five days following the final training session. It would be useful for subsequent work to examine whether feedback improves communicative strategies at later time periods. Further, it would be of interest to know whether the individual skills of the children (i.e., executive functioning) interact with the benefit gleaned from such training programs. For example, future studies could investigate whether children with larger working memory capacities show greater improvement through training compared to children with smaller working memory capacities.

Although this research has shed light on the cognitive skills involved in children's communication repair, it is not without its limitations. One limitation, as discussed in the results section, is that as working memory and cognitive flexibility are associated with the quality of children's initial statements, the degree to which the analyses used could capture the relationship of these skills with repair was limited. To address this issue, data was also analyzed while controlling for children's initial responses. Such analyses yielded consistent results, suggesting that results were not obscured by the limited ability to capture a relationship. Second, the task used was somewhat artificial in nature (e.g. children were told to describe specific targets to the confederate, the children did not receive any rewards for providing effective messages, and the confederate provided scripted responses). This may have reduced children's motivation to produce effective messages, a factor which has been shown to contribute to the effectiveness of their referential statements (Varghese & Nilsen, 2013). However, Fagan (2008) used a more naturalistic task and found that preschoolers often repeated their initial messages following feedback that miscommunication had occurred, suggesting that the present task likely did not reduce children's motivation beyond everyday communicative contexts. Also, due to time constraints only one task was used to measure each component of executive functioning included in this study, which prevented the use of latent variable analyses. Using latent variables is beneficial since this strategy can reduce the influence of random and measurement error on results (Russell, Kahn, Spoth, & Altmaier, 1998). Further, due to time limitations, children's general intelligence was not assessed in the present study. Thus, the extent to which children's executive functioning uniquely related to their communication skills independent of intelligence could not be assessed. However, verbal skills were assessed and controlled for in all analyses, with this skill (i.e., verbal skills) showing a strong correlation with children's intellectual ability (e.g., Childers, Durham, & Wilson, 1994). Additionally, as was previously mentioned, the distribution of data for the inhibitory control task used for the present study was negatively skewed. Many children were reaching ceiling on this task, which may have masked any potential associations between children's inhibitory control skills and their communication skills.

Another limitation of the study was that a large amount of variance in children's communication skills that was not explained by the reported models. This suggests that there are other factors which were not investigated that contribute to children's ability to produce and repair messages effectively. It is possible that other cognitive skills, such as processing speed and auditory attention, played a role in children's communicative skills. Processing speed may facilitate children's communicative skills since the ability to process information more efficiently frees up more cognitive resources to be used for more complex forms of cognition, which would be required when producing or repairing messages. Indeed, past research has found that children's processing speed is a significant predictor of their language skills (Leonard et al., 2007). Further, auditory attention also likely plays a role in children's ability to repair their messages, since children would be required to attend to the listener's feedback in order to determine that they had been misunderstood. Another factor which may have contributed to children's communicative skills is their understanding of social pragmatics. Children with a stronger understanding of social pragmatics and those who were not reticent to correct the confederate's incorrect object choices may have been more likely to repair their messages following feedback, as they would recognize that such a response was expected. Future work could investigate the role of other cognitive and socio-communicative factors which contribute to the effectiveness of children's production and repair strategies.

Overall, findings elucidate the role of working memory and cognitive flexibility in late preschool-aged children's ability to produce effective referential statements as well as the role of cognitive flexibility in their ability to repair their messages. These findings contribute to a growing literature demonstrating the importance of executive functioning for specific aspects of children's communication skills. Findings also highlight the benefits of specific feedback in facilitating communication repair. These findings provide greater understanding into the way in which cognitive skills impact children's communicative development and have implications for interventions targeted to improve children's communication skills.

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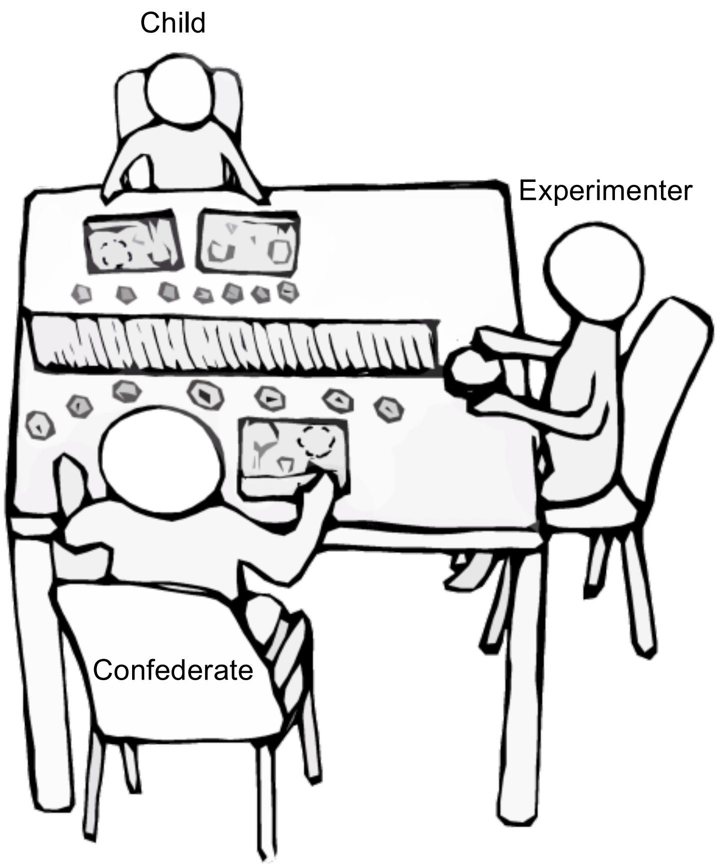

Figure 1. Layout for the communication task.

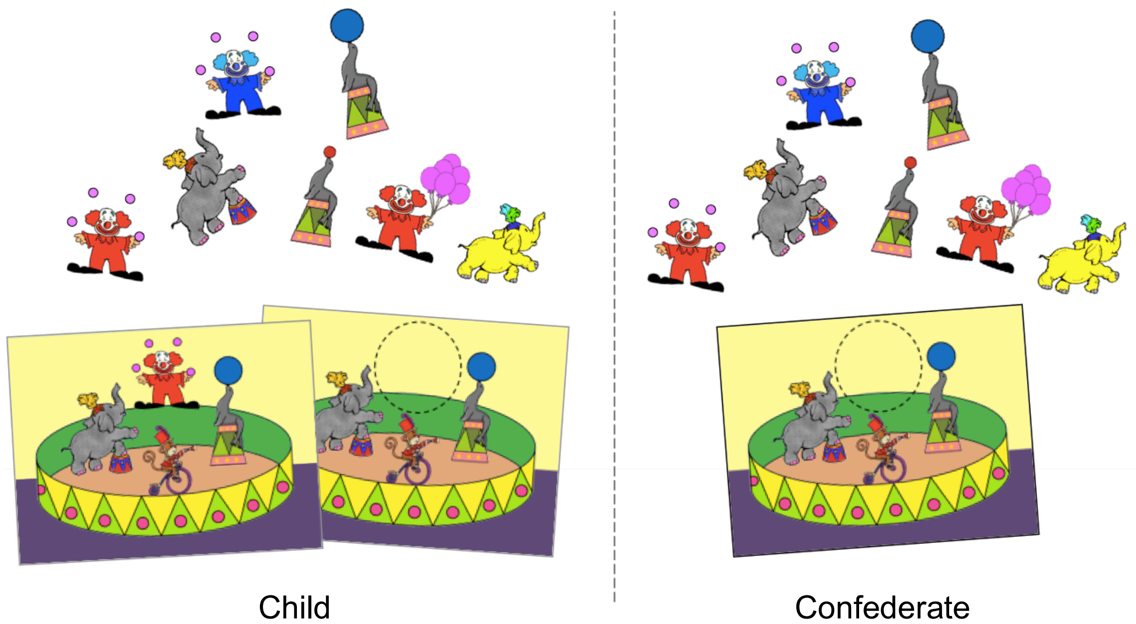

Figure 2. Stimuli used for the communication task. The child was given an incomplete and complete scene card (see left panel) during each trial, whereas the confederate was only given an incomplete card (see right panel). Both the child and confederate were provided with the same pictures (see top of both panels).

Table 1

Bivariate and partial correlations between measures of executive functioning (n = 112).

	Expressive Vocabulary	Digit Span	Red Dog/Blue Dog	Object Classification Task
Age	$.35^{**}$	$.30^{**}$	.13	$.29^{**}$
Expressive vocabulary		$.41^{**}$	.15	$.32^{**}$
Digit span			$.28^{**}$ ($.24^{*}$)	$.23^{*}$ (.08)
Red Dog/Blue Dog				$.14^{*}$ (.09)

Note. Partial correlations controlling for age and verbal skills are in parentheses
* $p < .05$; ** $p < .01$

Table 2

Mean number (SD) of behaviours during initial responses and following differential feedback from the listener.

	Feedback Type	
Behaviour	Detailed	Vague
Initial response behaviour		
Number of descriptors	.77 (.60)	.68 (.53)
Number of points to target	.06 (.13)	.15 (.24)
Repair behaviour		
Number of new descriptors	.69 (.49)	.44 (.44)
Number of points to target	.11 (.20)	.12 (.23)
Number of Repetitions	.10 (.18)	.24 (.30)
Number of trials with no response	.16 (.32)	.27 (.38)

Table 3

Mean number (SD) of descriptors provided during initial responses across trials within the Detailed and Vague feedback conditions.

	Trial Number					
Feedback Type	1	2	3	4	5	6
Detailed	.47 (.70)	.72 (.84)	.87 (.79)	.91 (.84)	.91 (.88)	.91 (.77)
Vague	.45 (.72)	.45 (.69)	.84 (.74)	.89 (.79)	.75 (.82)	.76 (.77)

Table 4

Bivariate and partial correlations between executive functioning measures and communication measures (n = 112).

	Number of descriptors (initial response)	Number of new descriptors (repairs)
Age	$.32^{**}$	$.22^{*}$
Expressive vocabulary	$.36^{**}$	$.30^{**}$
Digit span	$.39^{**}$ ($.27^{**}$)	$.22^{*}$ (.10)
Red Dog/Blue Dog	.13 (.07)	.05 (-.02)
Object Classification Task	$.33^{**}$ ($.21^{*}$)	$.28^{**}$ ($.22^{*}$)

Note. Partial correlations controlling for age and verbal skills are in parentheses
* $p < .05$; ** $p < .01$