

The Role of Executive Functions and Emotion Knowledge in Children's Communication Repair

by

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Author's Declaration

This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Statement of Contributions

Sarah Bacso was the sole author for the General Introduction and the General Discussion, which were written under the supervision of Dr. Elizabeth Nilsen and were not written for publication.

This thesis consists in part of two manuscripts written for publication. Exceptions to sole authorship of material are as follows:

Research presented in Study 1:

This research was conducted at the University of Waterloo by Sarah Bacso under the supervision of Dr. Elizabeth Nilsen. Sarah Bacso designed the study with consultation from Dr. Elizabeth Nilsen. Janel Silva collected the data for the study. Sarah Bacso was responsible for data analysis and drafted the manuscript, to which Dr. Elizabeth Nilsen contributed intellectual input.

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Research presented in Study 2:

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As lead author of these two studies, I was responsible for conceptualizing study design and data analytic planning, carrying out data analyses, and drafting and submitting manuscripts. My coauthors provided guidance and/or input during each step of the research and provided feedback on draft manuscripts.

Abstract

Young children often provide insufficient information when speaking with others, making the ability to identify miscommunications and repair inadequate messages essential skills within their set of communicative abilities. Previous work has investigated children's ability to detect and repair miscommunications in response to verbal cues from their listeners, but no work has explored their ability to do so in response to nonverbal cues from a listener. Study 1 assessed children's ability to detect and repair miscommunications in response to nonverbal cues provided by a listener. Children (ages 4 to 6) provided a virtual child listener with instructions on how to find a prize. If the child provided a uniquely identifying message, the listener looked happy after presumably finding the prize. If the child provided an ambiguous message, the listener appeared sad after presumably failing to find the prize. Children demonstrated awareness, through ratings, as to whether or not the listener found the prize on each trial, based solely on her facial expression. Children were also more likely to attempt to repair their messages on trials where the listener appeared sad. With respect to individual differences, children with stronger executive functioning (as indexed by a latent variable) and emotion knowledge were more accurate in their ratings of communicative success. Children with stronger emotion knowledge were also more likely to attempt to repair their messages when the listener appeared sad. Overall, findings from Study 1 suggest that children are able to make use of nonverbal cues from a listener to detect and repair miscommunications. Findings also suggest that executive functioning and emotion knowledge support children's ability to detect and repair miscommunications. Study 2 compared children's ability to detect miscommunications and immediately repair their messages in response to different types of listener feedback. That is, children were provided with an opportunity to respond directly following the listener's affective response (rather than after questions) and prior to the listener's selection of prize location. After providing an ambiguous message, children (ages

4 to 6) were provided with feedback indicating the listener was confused. Children were more likely to attempt to repair their messages following verbal cues from the listener compared to a baseline condition (i.e., a listener pause). Notably, nonverbal feedback (i.e., a confused facial expression) was no better than the baseline condition at eliciting communication repair. The combination of verbal and nonverbal cues was also no more effective at eliciting communication repair than verbal cues alone. Interestingly, children frequently attempted to repair their messages in the baseline condition, which consisted only of a listener pause. When executive functioning components were examined individually, working memory was found to be associated with children's likelihood of attempting to repair their messages, and with the quality of children's repairs. Emotion knowledge was found to be associated with the quality of children's repairs. The findings of Study 2 suggest that children are able to repair their messages in response to nonverbal feedback (given that they attempted to repair even in the baseline condition), but that they are more likely to repair their messages in response to verbal feedback. Findings also highlight the important role of executive functioning and emotion knowledge in children's communication. Results from these two studies have theoretical implications for children's communicative development, as well as implications for research methodology, the measurement of executive functioning, and interventions targeted to improve children's communication skills.

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General Introduction

Communication is a complex process wherein conversational partners are continually attending to each other's cues and modifying their own behavior accordingly. In this way, communication is like a dance where each person plays an integral role, both receiving and providing input in a reciprocal fashion. Both communicative partners carry out individual roles as well as joint ones (Clark, 1996), and a conversation between two partners results from the coordination of their individual efforts. Just as a waltz between two partners is not the same as the sum of the individuals' actions, a conversation involves two partners working together coactively, including making adjustments when missteps occur. A key aspect of communicative competence is the ability to attend to, and use, the cues from one's communicative partner in order to coactively build a conversation.

The development of communicative competence is one that extends throughout childhood and adolescence. For children to communicate effectively, they must attend to the context, the knowledge state of the listener, and cues in the communicative environment. Although children demonstrate remarkable sensitivity to others' perspectives early in life (e.g., Akhtar et al., 1996; Köymen et al., 2016; Matthews et al., 2006; Nayer & Graham, 2006; Nilsen et al., 2008), it is not until later that they develop communicative competence (Lloyd et al., 1998). The development of children's cognitive skills throughout the preschool years allows them to integrate information about the listener's perspective, the context, and cues provided, such that they can develop into effective speakers (Lloyd et al., 1998). Through the support of advancing cognitive skills, children progress from rudimentary communicative gestures such as pointing and making eye contact, to having full conversations.

Despite such advances, miscommunication is prevalent within the preschool and school-age years (e.g., Glucksberg, et al., 1966; Krauss & Glucksberg 1969; Lloyd et al., 1998;

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Pechmann & Deutsch, 1982), thus, a key aspect of developing communicative competence is the ability to detect and repair such miscommunication. When communicative partners are interacting, the speaker can draw on a number of cues from the listener to determine whether their message was (or was not) successfully understood. For instance, if I were to ask my friend to pass me “the photo” and there were several photos in front of her, she might make a confused facial expression, and she might ask me, “which one?”. Picking up on the nonverbal and verbal cues of confusion she provided, I might then choose to repair my original message by providing additional detail about which photo I wanted.

While past work has explored children's ability to repair their messages in response to verbal feedback from a listener indicating they have been misunderstood (e.g., Bacso & Nilsen, 2017; Coon et al., 1982; Deutsch & Pechmann, 1982; Nilsen & Mangal, 2013; Uzundag & Küntay, 2018), limited work has assessed children's ability to repair their messages following nonverbal feedback. Further, the socio-cognitive skills that support children's ability to detect and repair miscommunications in response to nonverbal feedback remain unknown. This thesis examines the development of children's communicative competence while acting as speakers. More specifically, in my doctoral research I explore children's ability to use verbal and nonverbal cues to identify when miscommunications have occurred, and to use this information to guide their attempts at communication repair. I also assess the role of children's cognitive skills (executive functioning and emotion knowledge) in their ability to repair their messages. In the following section, relevant background literature upon which my studies are formed is discussed.

Children's Communication Skills

Children's communication skills are key to their well-being and to the development of their social skills. Indeed, longitudinal studies indicate that children with specific language impairment, and related communicative challenges, are more likely than typically developing

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children to develop emotional problems such as anxiety and depression (see Yew and O'Kearney 2013 for a meta-analysis). Preschoolers with stronger communicative abilities are also less prone to emotional problems than their peers (Mackie & Law, 2010; St. Clair, et al., 2011).

Communication skills are also key for children's social competence. For example, preschoolers with stronger communicative skills are rated as being more well-liked by their peers (Hazen & Black, 1989); school-age children with stronger communicative abilities tend to be more popular among their peers (Gottman, et al., 1975; Kemple et al., 1992), and have fewer behavioral problems (Helland et al., 2014). Communicative deficits are aspects of diagnostic criteria for several disorders (e.g., autism spectrum disorder, social communicative disorder) and comorbid features of others [e.g., attention-deficit/hyperactivity disorder (ADHD; Carruthers et al., 2021) and developmental language disorder (Conti-Ramsden et al., 2019)]. Given the importance of children's communication skills for numerous other aspects of development, it is important for researchers to elucidate factors that contribute to children's ability to communicate effectively.

Often when the term 'communication' is used it is referring to acts that would fall under the umbrella term of pragmatic language. While there is no single agreed upon definition of pragmatic language, many approaches define pragmatic language as the ability to use language to interact with others appropriately and effectively (O'Neil, 2014). Pragmatic language includes a variety of specific skills, including the ability to initiate a conversation, to respond with relevant information, to use the context to produce and understand messages, to recount coherent narratives, and to understand non-literal language such as irony (Matthews, et al., 2018).

Children show increasing sophistication of their pragmatic language skills throughout their infant and early years. Typically developing children begin to show communicative behaviors within the first weeks and months of life, by synchronizing their patterns of eye gaze, movements, facial expressions and vocal turn-taking (Fernald, 1992). At around 9 or 10 months of age,

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children begin to intentionally communicate using gestures, vocalizations, and eye contact (Bates et al., 1975). These nonverbal communication patterns express a variety of intentions, such as requesting objects, rejecting offers, calling attention to objects and events, and to provide others with information (Bates, 1976; Carpenter, et al., 1998; Liszkowski et al., 2006). At the age of approximately 10 to 14 months, children across a variety of cultures begin to communicate with others through pointing (Liszkowski et al., 2011). By 2 years of age, children are able to engage in a number of communicative acts such as asking questions, negotiating, and discussing (Ninio & Snow, 1996). Children's communication skills increase rapidly during the preschool years (O'Neil, 2007). As will be discussed in detail within later sections of this thesis, throughout the school age years, children become more proficient in adapting their language to meet the needs of their conversational partner (Clark, 2003; Lloyd et al., 1998; Nilsen & Graham, 2009). Children also become better able to follow conversational rules, such as providing information that is relevant to a conversation (Ackerman, 1981). In addition, they develop other communicative skills such as the ability to understand non-literal language (Fillipova & Astington, 2008), and to lie (Talwar et al., 2007). Thus, a number of children's communicative skills develop rapidly throughout the preschool and school-age years.

One key pragmatic language skill is referential communication. Referential communication refers to communicative acts that involve referring to people, places, objects, or ideas (Asher, 1979). For example, it could involve asking a friend to pass you a photo as described previously, or could be more complex, such as teaching a colleague how to use a computer program. This thesis assesses how children attend to cues from their conversational partner to guide their communication repairs, after misunderstandings in referential communication have occurred. Before discussing children's abilities in this area, the principles guiding effective communication are discussed.

Maxims of Communication

Grice (1975) posited several maxims of conversation that communicative partners usually abide by to ensure effective communication, several of which are relevant to referential communication. He posits that effective communication involves cooperative efforts between individuals with a common purpose or mutually accepted direction. This “cooperative principle” refers to the notion whereby participants in a conversation work together and mutually accept one another to be understood in a particular way. This cooperative principle is divided into four maxims of conversation, called the maxims of quantity, quality, relation, and manner.

The maxim of quantity states that individuals aim to be sufficiently informative, but not over-informative in providing a message, such that effective communication ensues. The maxim of quality posits that speakers should be truthful. It suggests that one should not say things which they know to be false, or for which they lack sufficient evidence. The maxim of relation refers to the relevance of what is said, stating that speakers should provide information relevant to the conversation at hand, while avoiding irrelevant information. While the other maxims refer to *what* is said, the maxim of manner refers to *how* it is said. Specifically, it states that speakers should make their messages as easy as possible for the listener to understand. It 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).

Past work has found that children hold expectations that speakers will follow these maxims. For instance, work by Eskritt and colleagues (2008) found that 3- to 5-year-olds were more likely to ask a puppet for help with a game if it followed the Gricean maxims of quality and relation. Four- and 5-year-olds, but not 3-year-olds, were also sensitive to the maxim of quantity. Recent work by Panzeri and Foppolo (2021) also explored preschoolers', school-age children's, and adults' sensitivity to the Gricean maxims, and found that all age groups were sensitive to the

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maxims of manner, quantity, and relation. Notably, all participants were more tolerant of infringements of the maxim of manner than they were towards infringements to the maxims of quantity and relation. Thus, children as young as 3 years of age appear to be sensitive to whether these maxims are followed during conversation.

While the past work cited above demonstrates that children and adults are *sensitive to* the maxims of manner, quantity, and relation, other work has honed specifically on whether speakers and listeners tend to *adhere to* maxim of quantity during communicative exchanges. This line of work has had mixed findings with one study finding that adult speakers frequently over-describe targets in a referential communication task, and that listeners do not judge over-descriptions to be any worse than more concise descriptions of a target (Engelhardt et al., 2006). However, while listeners did not judge over-informative messages to be worse than concise ones, eye-tracking data suggested that over-informative messages led to momentary confusion. Other work with some methodological differences found that adults were less likely to over-describe targets than in Engelhardt et al., and that listeners appeared to be sensitive to both over- and under-informative messages, thus following the maxim of quantity (Davies & Katsos, 2013; methodological differences between these studies are discussed in Engelhardt, 2013). Thus, the existing research demonstrates that adults are sensitive to the Gricean maxims but may only follow these maxims under certain conditions.

The maxims of communication can also be studied in the context of the referential communication task, in that, within referential communication the speaker and listener coactively work together to ensure the intended message is accurately received. The maxims most relevant to study within referential communication tasks are the maxims of quantity and of manner, given the assumption that, within this context, all individuals would provide relevant and true information. A speaker may provide too little information, or provide too extensive a description of a target,

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thus failing to follow the maxim of quantity. Similarly, a speaker may provide an ambiguous message about a target, thus failing to follow the maxim of manner. As will be discussed further, despite their sensitivity to the maxims (Eskritt et al., 2008; Panzeri & Foppolo, 2021) young children frequently fail to provide enough information for their listeners (thus not using the maxim of quantity effectively) and provide ambiguous messages (thus not using the maxim of manner and quantity effectively).

The focus of this thesis is children's ability to produce effective referential messages, and importantly, their ability to repair misunderstandings when they occur. In the following sections, the extant literature on children's effectiveness as speakers will be reviewed. As well, studies on children's ability to successfully interpret/comprehend others' referential intent will be discussed.

Children's Referential Communication

A speaker's goal in referential communication is to identify an intended referent such that the listener would be able to identify this referent without mistaking it for other referents. Over several decades a referential communication paradigm (originally designed by Glucksberg et al., 1966) has been used to study children's ability to do this (e.g., Krauss & Glucksberg, 1969, Lloyd et al., 1998; Pechmann & Deutsch, 1982). During these tasks, children are required to uniquely identify a target object, which is amongst several similar distractors. Because there are similar distractors that could be confused with the intended referent, children must provide a detailed description of the target referent to provide a uniquely identifying message. Speakers and listeners are often separated by a screen to prevent the use of more simplistic strategies of identifying the target referent, such as pointing.

Mirroring the process that occurs within everyday exchanges, within a referential communication task, successful generation of a description that uniquely identifies the target object requires several steps. First, a speaker must notice the target referent and perceive its

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characteristics while also scanning nearby objects for similar distractors. They must also consider the perspective of their listener (i.e., which similar distractors can the listener see and not see?). They must then consider which distinguishing features they should include in their message to the listener to avoid message ambiguity. And finally, they need to generate and deliver a statement while holding in mind these pieces of information.

Early work using the referential communication paradigm found that young children (e.g., ages of 4 and 5) often have difficulty providing enough information, resulting in the provision of under-informative messages for their listeners (e.g., Glucksberg, et al., 1966; Krauss & Glucksberg 1969; Lloyd et al., 1998; Pechmann & Deutsch, 1982). For example, a young speaker might request that a listener pick up "the red one" when there are several different red objects the listener could choose from. Children's effectiveness as speakers improves rapidly between ages 5 to 10, with children beginning to provide more information for their listeners during referential communication tasks (Krauss & Glucksberg, 1969; Lloyd et al., 1998; Pechmann & Deutsch, 1982). For instance, Lloyd and colleagues (1998) found that by the age of 11 children were able to ask speakers for clarification about ambiguous messages and provide uniquely identifying messages for a listener on most trials. When they were 5 years-old they usually failed to request clarification from the speaker and were unable to provide the listener with critical attributes about the target object.

Past work has sought to elucidate the different processes involved in referential communication, as well as children's abilities to manage the demands of the process to gain further insight into what specific aspects may be creating difficulty.

Perspective-Taking

Early researchers believed that young children's difficulty with referential communication tasks could be attributed to a failure with taking into account the listener's perspective. Namely,

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the idea was that young children were what Piaget (1926) termed “egocentric” in their communication. Piaget believed that children did not develop the capability to consider another’s perspective until age 7 or 8.

However, the type of perspective-taking required for referential communication tasks is simplistic and only requires that children reason about their communicative partner’s visual perspective and consider what their partner can and cannot see. This relatively simple form of perspective-taking is acquired as early as one year of age (Luo & Baillargeon, 2007; see Baillargeon et al., 2010 for a review). Thus, it is unlikely that this would account for children’s difficulty with referential tasks. Moreover, in contrast to the idea that children are egocentric, extensive work suggests that young children are in fact aware of, and able to use, their communicative partner’s perspective during communication (e.g., Akhtar et al., 1996; Köymen et al., 2016; Matthews et al., 2006; Nayer & Graham, 2006; Nilsen et al., 2008). Within referential communication, several studies have demonstrated children’s ability to use a listener’s perspective to guide their production of messages (e.g., Bahtiyar & Küntay, 2008; Nadig & Sedivy, 2002; Nilsen & Graham, 2009; Nilsen & Graham, 2012; Wardlow & Heyman, 2016). For instance, Nadig and Sedivy (2002) found that 5- and 6-year-olds took into account which objects their listener could and could not see during a referential communication task. More specifically, children provided more descriptive information when there were two similar objects visible from the listener’s perspective relative to when the listener could only see one of the objects (even though the child could see both objects). In summary, young children appear to be able to account for their listener’s perspective while producing messages during simple referential communication tasks.

While it is agreed upon that children (ages 3 and above) are able to incorporate their communicative partner’s perspective into their communicative behaviors, accounts differ as to

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whether children and adults incorporate this information immediately into their comprehension and production of messages (early integration accounts), or whether this integration occurs at a later stage of processing (late integration accounts; see San Juan et al., 2015 for a review). The work of Nadig and Sedivy (2002) supports an early integration account since during a comprehension task, children quickly fixated on the target object after receiving instructions, even on critical trials where they, but not the speaker, could see a similar distractor object. In contrast, the work of Epley, Morewedge, and Keysar (2004) supports a late integration account. These researchers found that children and adults both initially interpreted instructions in an egocentric way, and then corrected their initially egocentric interpretation. That is, both children and adults tended to initially look at an object the speaker could not see and thus could not be referring to. Children in Epley and colleagues' study were also slower to fixate on the target object compared to those in Nadig and Sedivy's study. Keysar (2007) argues that children and adults adopt others' perspectives only after initially anchoring on their own perspective. They then effortfully account for differences between themselves and others (see Epley, Keysar, Van Boven, & Gilovich, 2004; Epley, Morewedge, & Keysar, 2004; Horton & Keysar, 1996; Keysar et al., 1998). The differing findings noted are likely attributable to methodological differences across studies. Thus, while the literature clearly demonstrates that young children (ages 3 and above) can use a conversational partner's perspective to guide their communicative behaviors, exactly when this integration occurs during the process of production or comprehension is unclear.

To summarize, existing evidence suggests that young children are able to take their listener's perspective into account during communication, which makes it unlikely that difficulty with perspective-taking alone accounts for their poor performance during referential communication tasks. Rather than perspective-taking constraining young children's

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communication skills, young children may have difficulty with referential communication due to the processing demands of producing effective messages.

Visual Scanning

To successfully account for the context during referential communication, speakers must visually scan the array of possible referents. Doing so allows for the detection of similarity across the referents, which ideally results in avoiding ambiguous referential statements. Several studies have examined adults' and children's ability to visually scan arrays during referential communication tasks.

For instance, Davies and Kreysa (2017) investigated whether adults fixate on contrast objects (i.e., a similar object to the intended, target object; e.g., a large ball when the target object was a small ball) before providing a uniquely identifying message. They found that speakers were more likely to be uninformative (that is, provided an ambiguous message) if they never fixated on the contrast object. Speakers were most likely to be informative if they fixated on the contrast object for longer before starting to speak. Notably, fixations to the contrast object were not essential for informative messages, with some speakers providing uniquely identifying messages even without directly fixating on the contrast object. This suggests that speakers can use information from their peripheral vision to guide their production of messages. The authors concluded that fixations to contrast objects are helpful for providing uniquely identifying messages but are not essential. Though, some awareness of the contrast object, perhaps through speakers' peripheral vision, is likely required for the generation of descriptions that uniquely identify target objects.

Further work by Rabagliati and Robertson (2017) similarly found that adults tended to look at contrast objects before providing a message to the listener. They also found that adults tended to look at contrast objects again after providing a message for the listener. The authors

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suggested that this was representative of participants self-monitoring their messages for ambiguity. In contrast, children (ages 3 to 5) usually did not tend to look at contrast objects before providing a message for a listener and usually provided ambiguous messages. On trials where they did produce a uniquely identifying message, they did look at the contrast object. This suggests that while preschool-aged children are able to engage in monitoring for ambiguity, and subsequently provide uniquely identifying messages, they frequently fail to do so. Children also usually looked at contrast objects after providing messages for the listener, suggesting that they do self-monitor for ambiguity. Interestingly, the authors found that children very rarely offered repairs for their messages even after they appeared to engage in this self-monitoring.

In contrast to the aforementioned study (Rabagliati & Robertson, 2017), Davies and Kreysa (2018) found that 4-year-olds fixated on contrast objects before producing a message for a listener to a similar extent as both 7-year-olds and adults. However, 4-year-olds were less likely than older children or adults to produce a uniquely identifying message. Regardless of the extent to which the 4-year-olds looked at the contrast object before speaking, they still produced ambiguous messages. Conversely, when 7-year-olds looked longer at the contrast object, they were more likely to provide a uniquely identifying message.

The research on children's visual scanning behavior suggests that scanning the target object and contrast object before attempting to provide a message can be helpful but does not always lead to effective messages. Namely, it is necessary, but not sufficient for success. For instance, Rabagliati and Robertson (2017) demonstrated that children sometimes provide uniquely identifying messages if they fixate on the contrast object before speaking. In contrast, the work of Davies and Kreysa (2018) suggests that even when children *do* look at a contrast object before speaking, they still tend to provide ambiguous messages. Thus, it appears there must be other reasons children tend to provide ambiguous messages during referential communication tasks.

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One hypothesis, discussed further below, is that the cognitive demands of providing effective messages are too high for young children.

In summary, children are required to integrate multiple sources of information about the listener's perspective and the context in order to provide effective messages during a referential communication task. Around the age of 3, children show the ability to incorporate the perspective of a communicative partner into their exchanges. Around the age of 7 they are more consistently able to incorporate information gleaned from scanning an array into their referential statements. Despite these advances, children's referential communication skills show continued development into their school-age years.

Communication Repair

As mentioned previously, although there are substantial gains in children's communication skills throughout their preschool years, they continue to produce ambiguous referential statements into their early school-age years (e.g., Lloyd et al., 1998). Indeed, even adults tend to overestimate the effectiveness of their own messages (Keysar & Henly, 2002). Thus, the process of detecting and correcting miscommunication is a key aspect of successful exchanges. In typical, everyday exchanges, when a young child produces an ambiguous message for a listener, they are often asked for clarification or provided with feedback. Communication repair refers to a speaker's ability to notice when miscommunication has occurred, and subsequently modify their message to improve its clarity for the listener. In this thesis, I examine children's ability to repair their messages when miscommunications occur. In particular, I investigate the role of listener feedback in children's ability to repair their initially inadequate messages. Past theoretical accounts suggest that adults are able to use cues from their listener to determine a message has been misunderstood and can also self-initiate repairs in the absence of listener cues (Schgloff et al., 1977); however,

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less is known about the processes through which children recognize their message has been ineffective.

Communication repair involves several steps. First, a speaker must recognize that their message has been ineffective. Second, they must decide to improve on their initial statement. Third, they must generate a repair statement that contains the necessary information to clarify the original message.

Looking at the first step of communication repair, existing work suggests that after the age of 4 children are indeed able to recognize when messages provided by others are unclear. For example, in past research, when children observed a speaker providing an unclear message for a listener, they demonstrated implicit behavior (i.e., eye gaze, and response latency) suggesting that they appreciated the message could be confusing (Nilsen et al., 2008; Nilsen & Graham, 2012). Four-year-olds were also able to detect message ambiguity when rating the quality of clues about the location of a hidden object (Gillis & Nilsen, 2014). Thus, it appears that young children can recognize when miscommunication has occurred (or could arise).

When acting as speakers in everyday exchanges, young children are often asked for clarification or provided with feedback when they provide an ambiguous message, thus aiding the child in detecting that their initial message was ambiguous. Receiving this type of feedback also makes the listener's perspective more apparent to children. Several studies have shown that preschool age children can benefit from verbal listener feedback indicating they have been misunderstood (e.g., Bacso & Nilsen, 2017; Coon et al., 1982; Deutsch & Pechmann, 1982; Nilsen & Mangal, 2013; Uzundag & Küntay, 2018). That is, following feedback, children provide additional information which disambiguates previously ambiguous referential statements. Moreover, the *type* of verbal feedback provided by the listener can influence children's ability to repair their messages (e.g., Anselmi et al., 1986; Bacso & Nilsen, 2017; Coon et al., 1982; Nilsen

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& Mangal, 2013; Uzundag & Küntay, 2018; Wilcox & Webster, 1980). For instance, Coon and colleagues (1982) found that providing children with specific feedback when they provided an ambiguous message (e.g., "There were several red ones and I picked the wrong one. I picked a red circle. Tell me whatever I need to know to pick the right one.") led to better repairs compared to when children were provided with vague feedback (i.e., "Tell me whatever I need to know to pick the right one."). Nilsen and Mangal (2013) found that providing preschoolers with an incorrect object which matched the child's ambiguous description elicited better repairs than when the listener verbally indicated that she did not understand.

Not only do children demonstrate the ability to immediately repair their responses following feedback from a listener, but they also demonstrate the ability to learn from such feedback to provide more effective initial statements during subsequent attempts. That is, providing children with feedback and giving them the opportunity to repair their statements appears to be an effective way of training them to provide more effective messages for their listeners (Abbot-Smith et al., 2015; Lefebvre-Pinard et al., 1982; Matthews et al., 2007; Matthews et al., 2012; Robinson & Robinson, 1981; 1985; Sarilar et al., 2015; Uzundag & Küntay, 2018; Wardlow & Heyman, 2016). For example, Matthews and colleagues (2007; 2012) found that preschool-aged children's descriptions of objects improved more rapidly across trials when they were provided with verbal feedback from the listener indicating they were misunderstood compared to in other conditions, such as one where they watched an adult provide detailed descriptions of objects.

Affective Cues

Affective cues are a type of nonverbal cue where information about an individual's internal state is conveyed, such as an individual's facial expression, gestures, and tone of voice (in this thesis, broadly encompassing both nonverbal emotional cues as well as cues to

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understanding). In addition to verbal feedback, conversational partners are continually providing affective cues that can be used to produce effective communication. For example, if I were trying to explain my research to a colleague, and they looked very confused, I would attempt to clarify what I was saying.

In this work, I focus specifically on children's use of affective cues from a listener to repair their initially inadequate messages. For example, are children able to detect that their message has been misunderstood if the recipient of their message looks sad (versus happy) or confused (versus content) after trying to follow their instructions? The two proposed studies of my dissertation aim to answer these questions and will also investigate the role of children's (socio-)cognitive skills, such as executive functioning and emotion knowledge, in supporting their communicative behavior.

Previous Research. Few studies have investigated children's ability to use affective cues to guide their production of referential statements. There is some existing work (albeit limited) showing that children take emotional cues from their communicative partner into account during communication. For example, work by Dunsmore and colleagues (Dunsmore et al., 2005) suggests that children can use emotional cues from a parent to highlight important aspects of a situation. This study found that children had better recall of their mother teaching them how to do a craft when their mother displayed emotions that were more typical for her. In addition, a recent study by Wardlow and Heyman (2016), found that 5- to 7-year-old children used nonverbal cues from a listener to provide more effective messages across trials (this study is discussed further in Study 1 and Study 2).

Existing work has also assessed children's ability to use affective prosody, referring to the emotional tone of a speaker's voice, to guide their *interpretation* of referential communication (see Graham et al., 2017 for a review). This line of work suggests that children use prosody to

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guide their interpretation of messages during referential communication tasks (Berman et al., 2010; Berman et al., 2013). For example, Berman and colleagues (2013) showed 5-year-olds images of a broken and an intact object (e.g., a broken and intact ball). Children were then given an ambiguous direction (e.g., "point to the ball") said with either sad prosody or happy prosody. Results indicated that children pointed to the intact ball when the direction was said in happy prosody, and the broken ball when sad prosody was used.

Further work suggests that 4- to 5-year-olds can reason about others' perspectives based on their emotional prosody and can use this information to guide their interpretation of communicative statements (Khu et al., 2017; San Juan et al., 2017). For example, a study by San Juan and colleagues (2017) found that 5-year-olds were able to use a speaker's happy or sad prosody to determine which of two objects the speaker was referring to when one object was disliked by the speaker, and the other was liked by the speaker.

While this line of work suggests that young children use affective cues to guide their communication, there are further areas yet to be assessed. For example, this work has assessed children's ability to use prosody to guide communication but does not examine whether children can make use of other affective cues such as facial expression, which would also be present in face-to-face interactions. Most notably, limited work has assessed children's ability to use a listener's affective cues to guide their performance as speakers. As such, it remains unclear whether speakers can use affective cues from the listener such that they generate more effective messages.

Socio-Cognitive Skills Associated with Communication

It has been posited previously that young children's difficulty with providing effective referential messages is due to the cognitive demands of doing so being too high (Davies & Kreysa, 2018; Nadig & Sedivy, 2002; Nilsen & Graham, 2009). Many cognitive skills influence

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children's ability to provide effective messages for a listener, and to effectively comprehend messages. As per the focus of this thesis, the following section provides a review of the literature examining children's executive functioning skills and their emotion knowledge skills, in relation to their communication abilities.

Executive Functioning

One set of cognitive skills that is thought to support children's ability to manage the demands of communication skills is their executive functioning. Executive functioning refers to a collection of cognitive skills that are used to control and regulate lower-level cognitive skills in order to attain goals (Alvarez & Emory, 2006).

Structure of Executive Functioning. In the literature, there are many models describing the structure of executive functioning. A model by Miyake and colleagues (2000) is one dominant description of executive functioning in adults. This model proposes that executive functioning is made up of three components of updating, shifting, and inhibition. These components are also referred to in the literature as working memory, cognitive flexibility, and inhibitory control, and these terms will be used throughout this thesis. Miyake and Friedman (2012) updated their model of executive functioning to include a common executive functioning latent variable, which accounted for the common variance between all executive functioning tasks. Interestingly, the common executive functioning latent variable corresponded exactly with the inhibition latent variable (i.e., inhibition had a factor loading of 1.0), which suggests that inhibitory control may be a foundational skill, with working memory and cognitive flexibility nesting within this factor.

While research suggests that elementary forms of working memory, cognitive flexibility, and inhibitory control exist in young children ages 3 to 5 (Garon et al., 2008), there are mixed findings as to the structure of executive functioning in this age range. For instance, some research suggests executive functioning has a unitary structure in young children (Brocki & Bohlin, 2004;

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Hughes et al., 2010; Nilsen, et al., 2016; Wiebe et al., 2011), while other research suggests executive functioning consists of two factors of working memory and inhibition. In the latter case, cognitive flexibility would load onto the working memory factor (Miller et al., 2012; Müller & Kerns, 2015). Karr and colleagues (2018) recently completed a review and re-analysis of many studies that used confirmatory factor models to test the dimensionality of executive functioning. They found that executive functioning is a unitary or two-factor structure in early childhood and becomes increasingly differentiated with development.

Role of Executive Functioning in Communication. Executive functions are thought to support the use of information about a communicative partner's perspective in guiding one's own communicative behaviors (see Matthews et al., 2018; Nilsen & Fecica, 2011), and several studies support this idea. Broadly speaking, there are two categories of studies which have assessed the role of executive functioning in communication. In some studies, the cognitive demands of the communication task are manipulated to ascertain the importance of particular cognitive skills. In other studies, children's executive functioning is measured and the relationship between individuals' executive functioning skills and their performance on communicative tasks is assessed. Further work has explored the communication skills of clinical populations in which executive functioning is thought to be impaired, providing a window into the potential role of executive functioning for communication.

Communicative Tasks with Varied Cognitive Demands. Ways in which cognitive demands have been manipulated in previous research include manipulations of the array size, of the similarity of distractor items, and having participants complete a secondary task simultaneously while completing a communication task. As described previously, young children under age 7 performed poorly on referential communication tasks (e.g., Pechmann & Deutsch, 1982). In Pechmann & Deutsch (1982) children (ages 2-6, and 9-year-olds) had to identify two or

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three dimensions of a target object (i.e., size, color, and shape), and differentiate it from an array of seven distractor items. These task demands likely placed a high cognitive demand on children and may have impacted their performance. Indeed, when array size is manipulated and task demands are lowered, such as in Nadig and Sedivy (2002; 5- to 6-year-olds) and Nilsen and Graham (2009; 3- to 5-year-olds), children perform better on referential communication tasks. In Nadig and Sedivy, children were only required to disambiguate the target from three distractor items and were only required to identify one dimension of the target object (i.e., size). Thus, it appears that simplifying task demands, which would reduce children's cognitive load, leads to improvements in their performance. Note that while some studies have directly manipulated the array size (e.g., Lloyd et al., 1998) or number of features to be described (Nilsen et al., 2015), differences in children's performance across these different conditions have not been reported. As a result, direct comparisons within a single study are not available. Relatedly, children, in the role of listeners, perform worse in studies where the description from a speaker is a better referential match to an object blocked from the speaker's view, than to an object (the target object) the speaker can see (e.g., "the smallest truck", in an array of three different sized trucks, with the smallest one blocked from the speaker's view, but the mid-sized truck (target object) and large truck visible; Epley, Morewedge, & Keysar, 2004; Nilsen et al., 2013) relative to studies where the speaker's statement equally applies to a visible (target) and blocked object (e.g., "the duck" when there are two different sized ducks; Nadig & Sedivy, 2002; Nilsen & Graham, 2009). The lower performance in the former is likely due to the added inhibitory control or cognitive flexibility needed to shift away from the contrast object (e.g., smallest truck, blocked from view) in order to correctly choose the object that the speaker would be referring to (e.g., a medium sized truck).

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A recent study by Malkin and Abbot-Smith (2021) manipulated the similarity of distractor items, such that, to be successful in their referential descriptions, children had to change the way they previously described an object to a listener. This manipulation (i.e., the switch condition) was intended to place demands on children's cognitive flexibility. More specifically, in this switch condition, children initially provided a simple description of a target when it was not amongst similar distractors (e.g., "the dog") and later had to modify their description when the same target was amongst similar distractors (e.g., "the spotty dog" when there was also a black dog present). In their no-switch condition no object needed to be re-described. They found that both autistic and typically developing children were less likely to be appropriately informative (i.e., not under-informative or over-informative) on switch trials than on no-switch trials. This demonstrates that children's cognitive flexibility skills are important for their ability to provide the correct amount of information to a listener.

Roßnagel (2000) assessed the impact of adding a cognitive load to speakers' referential statements. Participants (adults) in the study were asked to provide instructions on how to assemble a machine to an addressee. Cognitive load was manipulated based on whether or not the assembled model was in front of participants while they gave their instructions. In the high load condition, participants had to provide their instructions based on their recall of the assembled model. To assess the speaker's ability to tailor their instructions to the needs of the listener, participants had to provide the instructions to both a child and another undergraduate student. Roßnagel found that participants were more likely to adjust their references to the child compared to the adult addressee in the low cognitive load condition. When speakers had high cognitive load, they failed to adjust their messages based on the age of the listener. These findings suggest that working memory plays a key role in speakers' ability to effectively use the listener's perspective to guide their message production.

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Individual Differences in Executive Functioning. Several studies have also examined the relationship between individual differences in executive functioning and children's performance on various communicative tasks. For instance, past research suggests that when children are acting as speakers, executive functioning (working memory, cognitive flexibility, and inhibition) facilitates their ability to provide effective messages for their listeners during referential communication tasks (Bacso & Nilsen, 2017; Nilsen et al., 2015; see Wardlow, 2013 for similar results in adults). Bacso and Nilsen (2017) had children complete a referential communication task and found that their performance on the referential communication task was associated with their score on the Object Classification Task (Smidts et al., 2004), a test of cognitive flexibility. Similarly, Nilsen and colleagues (2015) found that children's working memory (as measured by the digit span task) and inhibitory control (measured by a stop signal reaction task) were significantly associated with their performance on referential communication tasks. The two referential communication tasks used were a multiple features task and a sequential naming task. On the multiple features task, children needed to provide detailed descriptions of the target picture to differentiate it from multiple, similar distractor pictures. On the sequential naming task, children were required to name one picture before naming the target picture. On cued trials, the picture that was named first was similar to the target picture (e.g., children described a bat [a flying animal], then a baseball bat), whereas on uncued trials the first picture that was named was dissimilar to the target picture. These conditions allowed for assessment of the degree to which highlighting potential referential ambiguity impacted children's performance. Children with stronger working memory and inhibition skills provided more relevant descriptors of the target during the multiple features task. Children's working memory, but not inhibition, was also found to be related to the quality of their descriptions on the sequential naming task.

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When children are acting as listeners, executive functioning (inhibition) appears to facilitate their ability to accurately interpret messages during a referential communication task (Nilsen & Graham, 2009; see Brown-Schmidt, 2009 for similar results in adults). For instance, Nilsen and Graham (2009) had children complete a referential communication task wherein some objects were blocked from the speaker's view. In their privileged ground condition, the target object (i.e., a large duck) was visible to both the speaker and the child and a referential alternative (i.e., a small duck) was visible only to the child. The speaker instructed the child to pick up the target object (i.e., "pick up the duck"). If the child were to successfully interpret the speaker's message, they should choose the duck that the experimenter could see and not the duck that was blocked from view from the speaker. The researchers found that children's choosing of the referential alternative, which was blocked from the speaker's view, was negatively associated with their inhibition skills (as measured by a modified Stroop task). Thus, children with weaker inhibitory control skills made more comprehension errors. Further, adolescents' working memory skills were found to be related to their ability to understand a speaker's communicative intentions (Nilsen & Bacso, 2017). In this study adolescents' perspective-taking skills were assessed using a video task wherein they were required to reason about a speaker's intended meaning based on their facial expression and tone of voice (the TASIT; Rollins et al., 2002) and a computerized task similar to that used by Nilsen & Graham (2009). The researchers found that a composite of these two perspective-taking tasks was associated with adolescents' working memory skills (as assessed using the digit span task).

Overall, it appears that executive functioning plays a role in children's communication skills, although there is inconsistency across studies in relation to the specific components. For instance, inhibition has been found to be associated with children's performance as speakers in referential communication tasks in one study (Nilsen et al., 2015) but not in others (Bacso &

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Nilsen, 2017; Nilsen & Graham, 2009). Some of this inconsistency may result from different tasks being used to assess executive functioning and referential communication, however, more research is needed to fully understand the specific nature of the relationship between executive functioning and children's communication.

Executive Functioning and Communication within Clinical Populations. A number of pediatric clinical populations have been found to exhibit deficits in their executive functioning, for example, children with autism spectrum disorder (ASD) and ADHD (Corbett et al., 2009). Several studies have also demonstrated that individuals with ASD and ADHD are impaired in their communication skills as well, which may be, in part, accounted for by their deficits with executive functioning.

Children with ASD are known to be impaired in a variety of communicative behaviors, including referential communication (see Tager-Flusberg et al., 2005 for a review). For instance, children with ASD (ages 7 to 14) provided fewer relevant features when describing a target object in a referential communication task compared to typically developing children (Dahlgren & Dahlgren Sandberg, 2008). Interestingly, in the previously mentioned study by Malkin and Abbot-Smith (2021), children with ASD were found to be over-informative when describing a target in a referential communication task. Thus, it appears that children with ASD are impaired in their ability to provide the level of detail necessary to provide a uniquely identifying message during a referential communication task. Children with ASD (ages 5 to 7) also adjust their instructions during a referential communication task less based on the listener's knowledge state compared to typically developing children (Malkin et al., 2018). Few studies have explored the role of executive functioning in the communication skills of children with ASD. Some studies have shown significant associations between executive functioning and socio-communicative skills (Leung et al., 2016; McEvoy et al., 1993; Kenworthy et al., 2009), whereas other studies

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have found no such association (Jones et al., 2017; Joseph & Tager-Flusberg, 2004; Kouklari et al., 2018; Landa & Goldberg, 2005).

Children with ADHD are also impaired in a variety of socio-communicative skills (see Green et al., 2014 for a review). Many studies have linked these communicative and social skills deficits to impairments in executive functioning (e.g., Bunford et al., 2015; Chiang & Gau, 2014; Huang-Pollock et al., 2009; Kofler et al., 2011; Mikami et al., 2009; Nilsen et al., 2015; Nilsen & Bacso, 2017; Tseng & Gau, 2013). For instance, in the previously mentioned study by Nilsen and colleagues (2015), it was found that children's effectiveness in a referential communication task was associated with their executive functioning skills and their ADHD symptomatology. Further, children's working memory skills were found to account for variance in the relationship between children's ADHD symptoms and their referential communication skills. Findings from this study suggest that the communicative challenges of children with elevated ADHD symptoms are attributable in part to weakness in executive functioning.

Together, findings from studies of children with both ASD and ADHD indicate that these populations are impaired in their socio-communicative skills. Some research indicates that the deficits seen in ASD may be partially attributed to deficits in executive functioning, although evidence is mixed and few studies have directly examined the association between executive functioning and communication skills in this population. Relatively more studies have explored the role of executive functioning in children with ADHD's communicative deficits and suggest that executive functioning plays a role.

The Role of Executive Functioning in Children's Communication Repair. In addition to supporting the generation of referential statements, executive functioning is thought to be important for children's ability to immediately repair their messages in response to feedback, and for their ability to benefit from feedback on subsequent trials. Volden (2004) posited that there

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were several steps involved in communication repair and that executive functioning supported children's ability to repair their messages. First, speakers must judge the listener's knowledge state, which would require theory of mind skills. Second, the speaker must compare the listener's knowledge state with their original message and determine which parts of the message were unclear. This step was proposed to involve working memory as speakers would need to hold information about the listener's knowledge state and their own previous message in mind while formulating a response. Lastly, the speaker must adjust their message based on the first two steps. Volden proposed that cognitive flexibility may be involved in communication repair since it requires children to shift from their original message to assessing and repairing the breakdown.

Previous research supports this idea that executive functioning skills support children's communication repair (Bacso & Nilsen, 2017; Uzundag and Küntay, 2018; Wardlow and Heyman, 2016). For instance, in my previous work (Bacso & Nilsen, 2017), we found that children with higher cognitive flexibility were better able to repair their messages in response to verbal feedback provided by the listener which indicated they had been misunderstood. Cognitive flexibility may aid children in repairing their messages by allowing them to view the target object's dimensions more flexibly. That is, children with stronger cognitive flexibility skills may be better able to identify both the target object's color *and* shape without becoming fixated solely on the color of the object. Such flexibility may aid children in detecting when ambiguity has occurred (see Gillis & Nilsen, 2014) and in knowing which additional information would be helpful to provide. Further discussion of the role of executive functioning in children's communication repair can be found in Study 1 and Study 2.

Communication Repair in Clinical Populations. Just as populations with executive functioning deficits have difficulty with referential communication, they also have impairments in communication repair. Communication repair has been found to be impaired in children with

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Fragile X syndrome (Fielding-Gebhardt et al., 2020; Martin et al., 2020) and ASD (Barstein et al., 2018; Paul and Cohen, 1982; Volden, 2004), and both of these populations have been found to show impairments in executive functioning, even when controlling for their overall IQ or mental age (Hooper et al., 2008; Kirk et al., 2005; Ozonoff et al., 1991; Ozonoff et al., 1995). While no studies have simultaneously examined the executive functioning deficits and communication repair skills of these populations, Volden (2004) proposed that executive functioning deficits may account for the deficits seen in communication repair skills for children with ASD.

Emotion Knowledge

While past work has found significant associations between children's executive functioning skills and their communication skills, there is still variability in children's referential communication skills that is unaccounted for (e.g., Bacso & Nilsen, 2017; Nilsen & Bacso, 2017). Thus, in addition to executive functioning, other individual differences likely play a role in children's communication skills. One skill that may influence children's communication skills is emotion knowledge. In this thesis I will refer to emotion knowledge as including both affective labelling, which involves the ability to name what emotions are being depicted by facial expressions of others, and emotion understanding, which involves understanding what situations are likely to elicit different emotions in others.

Although only a few studies have directly assessed children's ability to use affective cues to guide their communicative behaviors, many studies have shown that children's emotion knowledge is important for their broader social skills, of which effective communication would be one component. For example, preschoolers' emotion knowledge has been shown in observational studies to predict their behavior in response to seeing others' emotional expressions (Denham 1986; Denham & Couchoud, 1991). Past work has shown that young children with higher emotion knowledge also demonstrate higher social competence in the classroom as reported by

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their teachers (Bassett et al., 2012; Denham et al., 2003; Denham et al., 2012; Denham et al., 2015; Deneault & Ricard, 2013; Izard et al., 2001; Rhoades et al., 2009; Tang et al., 2021) and peers (Denham et al., 1990; Fabes et al., 2001; Garner & Estep, 2001). Research on older, middle school age children found that children's emotion knowledge is associated with their social skills and social problem-solving abilities, which then predict peer acceptance (Dodge et al., 2002; Mostow et al., 2002). In addition, interventions targeted to improve children's emotion knowledge have been shown to be effective, and also have a positive influence on children's social competence (e.g., Izard et al., 2008; Whitcomb & Merrell, 2012). Generally, it appears well accepted in the literature that children's emotion knowledge is key for their broader social skills.

Emotion Knowledge and Theory of Mind. Emotion knowledge is also thought to be a key component of theory of mind (see Dunn, 2000 for a review), which refers to the ability to recognize and reason about the mental states of others. This process of paying attention to a conversational partner's mental states is important for children's communication skills. No previous work has directly examined the role of emotion knowledge in communication, however, there is literature that has looked at theory of mind or perspective-taking (related constructs) as an individual difference measure in relation to communication (e.g., Resches & Pereira, 2007; Roberts & Patterson, 1983). While perspective-taking is important for children's referential communication (Nilsen & Fecica, 2011), it may not be the primary limiting factor for young children's performance on referential communication tasks, as mentioned earlier.

Emotion knowledge is similar to one component of theory of mind, known as affective theory of mind, referring to recognizing and reasoning about others' emotions. Early stages of affective theory of mind can be assessed using the same tasks used to assess emotion knowledge, such as matching emotion words to pictures of individuals, or to descriptions of situations (Westby & Robinson, 2014). Another component of theory of mind is cognitive theory of mind,

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which involves reasoning about others' beliefs and is often measured by tasks such as the false belief task (e.g., Wimmer & Perner, 1983). A recent meta-analysis found that both affective and cognitive theory of mind were associated with children's prosocial behavior (Imuta et al., 2016). Preschoolers' emotion knowledge is seen as a precursor for the development of cognitive theory of mind. This notion has been supported by longitudinal research (O'Brien et al., 2011; Carlson et al., 2013). In school age children, emotion knowledge is associated with their cognitive theory of mind, as assessed by the false belief task (Qualter et al., 2011). Researchers have theorized that the development of children's emotion knowledge alerts them to others' points of view, which helps them to better understand the minds of others, thus improving their theory of mind skills (Hughes & Leekam, 2004). With this in mind, it is plausible that children's emotion knowledge may support better communication.

The role of Emotion Knowledge and Executive Functions in Communication. Just as executive functions are thought to support children's communication, executive functions are also thought to support their ability to reason about others' emotional states. A limited number of studies have assessed the relations between executive functions and emotion knowledge, and findings are mixed. A study by Martins and colleagues (Martins et al., 2014) found that children with higher cognitive flexibility had higher emotion knowledge, controlling for age, IQ, language ability, and theory of mind. No relationship was found between inhibitory control and emotion knowledge once control variables were included. However, Rhoades and colleagues (Rhoades et al., 2009) found some evidence that inhibitory control was associated with preschooler's emotion knowledge (i.e., performance on a peg-tapping task, but not a day/night task was associated with emotion knowledge). Denham and colleagues (2012) conducted a longitudinal investigation, where results suggested that inhibitory control supports the development of emotion knowledge skills, rather than the reverse relationship.

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Thus, existing work indicates that executive functions and emotion knowledge are related to one another. There are several theoretical accounts explaining why emotion knowledge and executive functioning are related to one another (see Martins et al., 2014). One explanation is that executive functioning is required for the development of children's socio-cognitive competencies. For instance, cognitive flexibility may be required in order for children to shift from a valence-based emotional understanding to understanding discrete categories of emotions. Another possibility is that children with stronger executive functioning skills are better able to form relationships with others, which in turn helps to develop their socio-cognitive skills. A third possibility is that the relationship between executive functioning and emotion knowledge reflects similarities across the tasks used to assess these cognitive skills. That is, tasks used to assess emotion knowledge may draw on children's executive functioning abilities as well. It also may be the case that children require sufficient executive functioning skills to make use of their emotion knowledge skills to guide their communication. This suggests that research investigating the cognitive skills which support communication should include both executive functioning and emotion knowledge.

To my knowledge, only one study has simultaneously examined the role of executive functions and emotion knowledge in children's ability to use affective cues to guide their communication. This work by Khu and colleagues (2017) found that 4-year-olds demonstrated awareness (through eye gaze) of their partner's communicative intent based on their emotional prosody. To illustrate the task used in this study, the children and confederate were each assigned a small door they could open to receive prizes. During one type of trial, "potential win trials", children were allocated stickers behind their door on some trials, and a confederate was given stickers behind her door on other trials. The children would first hear the confederate's reaction to the sticker she had received (i.e., "Look there it is"), said in happy prosody if the sticker was

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behind the confederate's door, or said in sad prosody when the sticker was behind the child's door. The child was then given the opportunity to choose by pointing whether he or she wanted to take what was behind their own door or take what was behind the confederate's door. Children demonstrated awareness of which door the sticker was behind based on eye-tracking data (i.e., on potential win trials they looked at their own door when the confederate used sad prosody; and the confederate's door when happy prosody was used). They were also able to use this awareness to guide their pointing behavior on potential win trials. This study also assessed children's executive functioning (inhibitory control) and emotion knowledge. Results indicated there was no relation between inhibitory control and children's performance on the competitive task. Results also found that children with higher emotion knowledge were more likely to choose the appropriate door on potential win trials. In summary, children's executive functioning skills were not found to play a role in their performance on this communicative task, but their emotion knowledge skills were, suggesting a differential role of these cognitive skills in children's communication.

Overall Research Aims

The existing literature has demonstrated the importance of executive functions for children's ability to produce effective messages, and to repair their messages when they have been misunderstood. Past work also demonstrates the importance of emotion knowledge for children's broader social skills and has shown that young children can repair their messages in response to verbal feedback provided by a listener. However, the role executive functioning plays in children's ability to use cues from a listener, in particular affective cues, to support their production and repair of referential statements remains unknown. Further, the role of emotion knowledge in children's communication is largely unknown.

The set of two studies discussed here investigate the degree to which children use affective cues to guide their referential communication and also explore what mechanisms may underlie

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their ability to do so successfully. In the two studies, I assessed 4- and 5-year-old children's ability to use facial expression and linguistic cues to guide their communication. The two studies also demonstrate how children's executive functioning skills influence their effectiveness as speakers when providing initial messages and repairs in response to the affective cues of a communicative partner. Further, this work provides insight as to how individual differences in emotion knowledge influence children's communication skills.

Study 1 explored whether children use affective cues (e.g., happy or sad facial expression) that occur in response to the resulting effects of their communication (e.g., a listener finding the correct or incorrect object) to determine whether their message was accurately interpreted, as assessed by a series of questions and option to provide further information. Study 2 assessed the degree to which children use linguistic, and facial (i.e., confusion) listener feedback to determine when their message was unclear and in need of clarification prior to the listener's selection. In both studies, children completed measures of executive functions and emotion knowledge, and the relations between individual differences in these skills and their performance on communication tasks was assessed. These studies are described in detail in the sections that follow.

Both studies investigate questions not addressed in the existing literature and have implications for the theoretical understanding of how children's interactions with others contribute to the development of their communication skills (see Ateş-Şen & Küntay, 2015 for a review). These studies also have relevance for interventions targeted to improve children's communication skills (e.g., Matthews et al., 2007; Matthews et al., 2012), as discussed further in the General Discussion.

Study 1: How to turn that frown upside down: Children make use of a listener's facial cues to detect and (attempt to) repair miscommunication

The following chapter has been reproduced and adapted with publisher permission from: Bacso, S. A., Nilsen, E. S., & Silva, J. (2021). How to turn that frown upside down: Children make use of a listener's facial cues to detect and (attempt to) repair miscommunication. *Journal of Experimental Child Psychology*, 207, 105097. Please note that appendix information has been moved to be included in the body of the text for this thesis. The published version is available online at <https://doi.org/10.1016/j.jecp.2021.105097>

Background

As many parents attest, young children often have difficulty providing sufficient information for their intentions to be clear. There are several decades of studies examining children's ability to refer to objects, people, and events (i.e., referential communication) demonstrating children's initial failures in providing adequate descriptions of target objects for a listener (e.g., Deutsch & Pechmann, 1982, Lloyd et al., 1998). This initial ambiguity makes the ability to detect and repair miscommunication essential for the successful exchange of information, and as such, a key aspect of children's communicative development.

Consider the following example, a child wanting to direct their parent's attention to a car in the distance, says, "Look at the car." even when several cars of different models and colors are on the road, thus leaving their parent unable to effectively understand their communicative intentions. In such an instance, the parent would likely provide the child with verbal cues indicating they failed to understand their request (e.g., saying, "Which one?") as well as nonverbal cues indicating the message was misunderstood (e.g., making a confused facial expression). After receiving this feedback, the child might attempt to repair their message so that it can be successfully understood by the listener (e.g., "The green one").

The process of repairing miscommunication involves several steps, which may be supported by feedback from a communicative partner. First, a speaker must recognize that their communication has been ineffective, a process that can be facilitated through feedback from a communicative partner. Second, they must decide to improve upon their initial statement, and finally, they must generate a repair statement that, if effective, contains additional information to correct the miscommunication. In this way, the first and second steps are necessary pre-requisites to a successful repair, but do not guarantee successful execution.

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While past research has explored children's ability to detect and repair miscommunication in response to verbal feedback (e.g., Bacso & Nilsen, 2017; Coon et al., 1982; Deutsch & Pechmann, 1982; Nilsen & Mangal, 2012; Uzundag & Küntay, 2018), no research has examined this ability in response to purely nonverbal (i.e., affective) feedback. Further, only a handful of studies have sought to determine the cognitive skills that support children's repairs, and none have explored associations with the specific steps involved in children's communicative repairs. The present study addressed these gaps: The first aim was to examine children's ability to detect miscommunication after receiving only nonverbal listener feedback (i.e., a sad facial expression) indicating the child's message was misunderstood, and to, subsequently, repair their messages. The second aim was to examine the role of executive functioning (EF) and emotion knowledge (EK), in children's ability to identify and repair miscommunication in response to nonverbal feedback.

The Role of Feedback in Children's Communication

In general, interactive contexts, where a listener is an active participant in the exchange, are key to children's success in producing clear referential statements (Grigoroglou & Papafragou, 2019). Using cues from a listener, children are able to identify that their own message has been ineffective and is in need of repair. In the absence of any immediate feedback that indicates a misunderstanding has occurred, children do not appear to learn from their mistakes in communication. They tend to persist in producing ambiguous messages, and do not appear to recognize that their original message was inadequate. For instance, Robinson and Robinson (1985) found that 5-year-old children's communicative performance did not improve when the experimenter chose a correct object following ambiguous messages and then subsequently explained what was lacking in the child's message. Similarly, Wardlow and Heyman (2016) found that young school-age children provided more ambiguous descriptions on subsequent trials

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when an experimenter did not provide feedback versus a condition where feedback was provided.

In a context where an experimenter provided an alternate toy to that requested, but no other feedback, toddlers tended to abandon their initial attempts (Fagan, 2008). Thus, feedback appears to be essential for children to learn about the communicative needs of a listener.

With respect to the act of repairing messages specifically, when listeners provide verbal feedback indicating they misunderstood the message, children attempt to repair messages, suggesting that they are attuned to such cues from communicative partners (e.g., Anselmi et al., 1986; Bacso & Nilsen, 2017; Coon et al., 1982; Nilsen & Mangal, 2012; Uzundag & Küntay, 2018; Wilcox & Webster, 1980). However, the success of children's repairs depends on the type and quality of feedback provided. For instance, Bacso and Nilsen (2017) found that 4- and 5-year-old children were better able to repair messages that were initially misunderstood by the listener following feedback which specifically identified what was lacking in the child's original message (e.g., "there are three boys and I don't know which one you mean") compared to vague feedback (e.g., "I don't know which one you mean"). Other work has supported this finding that more specific verbal feedback benefits children's communication repair compared to vague feedback (Coon et al., 1982; Nilsen & Mangal, 2012; Uzundag & Küntay, 2018). In addition, repairing statements in response to feedback from a listener may be an important way through which children learn to be effective communicators. Matthews and colleagues (Matthews et al., 2007; Matthews et al., 2012) found that providing preschool-age children with specific verbal feedback, and giving them the opportunity to repair their messages, improved their ability to provide effective descriptions of target objects on subsequent trials during a referential communication task. When preschool-age children are provided with minimal feedback (e.g., "huh" or "what"), they often repeat their original messages rather than attempting to repair them (Anselmi et al., 1986; Nilsen & Mangal, 2012). Thus, it is likely that the type of verbal feedback influences all

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three steps of the repair process: helping children identify that a message is in need of repair, helping children decide to repair messages, and helping children to produce an effective repair message.

Nonverbal feedback, such as affective cues, may also aid children in recognizing when miscommunication has occurred, although this has not been directly examined. Work by Wardlow and Heyman (2016) provides some support for the notion that children use listeners' emotional cues during referential communication. In this study, 5- to 7-year-old children completed a communication task in which some objects were blocked from the listener's view. When children provided an ambiguous message, the listener either provided no feedback that a misunderstanding had occurred (i.e., smiled and chose the correct object) or provided nonverbal feedback indicating a misunderstanding had occurred (i.e., looked confused and chose the incorrect object). Children who received the nonverbal feedback provided more effective messages across trials compared to those who received no feedback. However, the fact that the nonverbal feedback used in this study included an incorrect object choice is important, as this feature in isolation is a particularly salient cue for prompting children to repair messages. That is, work by Nilsen and Mangal (2012), found that children often repaired their messages when the listener visibly chose the incorrect object. Thus, it is unclear whether children were responding to the confederate's affective cues or incorrect object choice. The extent to which children can make use of affective cues to guide their ability to produce effective messages for a listener remains unclear.

In addition to the visual aspects, emotional cues exist within the tone of communicators' voices. Past work has found that preschool-age children are sensitive to a speaker's emotional prosody and can use this cue to guide their interpretation of referential communication (see Graham et al., 2017 for a review). For example, a study by San Juan and colleagues (2017) found that 5-year-olds were able to use a speaker's happy or sad prosody to determine which of two

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objects the speaker was referring to when one object was disliked by the speaker, and the other was liked by the speaker. While this line of work suggests that young children can use affective cues when interpreting others' statements, it remains unclear whether they use affective information to *generate* effective messages, and if so, what skills support this process.

Socio-Cognitive Skills Associated with Communicative Repairs

Given the multiple steps involved in repairs (i.e., detecting miscommunication, deciding to repair, and generating a revised statement), it is likely that there are a number of supporting skills, with the focus in the current study on children's executive functioning (EF) and emotional knowledge (EK). Executive functioning refers to a set of cognitive skills which support goal-directed behavior. The components of EF assessed in the present study include working memory, inhibition, and cognitive flexibility. Emotion knowledge refers to children's ability to recognize emotional expressions, and to understand the situations that elicit emotions (Denham, 1998). Previous research suggests that EF and EK are interrelated, but separable constructs (Martins et al., 2016). Further, children with stronger EF skills are likely to develop stronger EK skills over time (See Denham et al., 2012). Both skills show associations with children's socio-communicative behavior (Bassett et al., 2012; Fabes et al., 2001; Matthews et al., 2018), though their role within specific aspects of repair is not known.

While there is some support for the notion that EF is related to children's ability to detect miscommunication (albeit in third person tasks; Gillis & Nilsen, 2014; Nilsen & Graham, 2012), past work in this area has tended to focus on the last step in the repair process (i.e., generating a successful repair). For instance, Wardlow and Heyman (2016) found that children's working memory was associated with their ability to improve their descriptions of target objects across trials when children received feedback on their performance. Interestingly, such relations were not found in a condition where feedback was not provided (similar to other studies showing no

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relation, e.g., Nilsen & Graham, 2009). Further, Bacso and Nilsen (2017) found that children with higher cognitive flexibility were better able to repair their messages in response to verbal feedback provided by a listener which indicated they had been misunderstood. Work by Uzundag and Kuntay (2018) had similar results, finding that cognitive flexibility, working memory, and short-term memory were associated with the quality of children's repairs. It has been reasoned that cognitive flexibility may aid children in repairing their messages by allowing them to view the target object's dimensions more flexibly. For instance, children with stronger cognitive flexibility skills may be better able to identify both the target object's color *and* shape without becoming fixated solely on the color of the object. However, it is unclear whether EF shows similar associations across all components of the repair process, particularly in a context where the feedback from the listener involves solely affective information.

Recognizing that a repair is necessary, particularly in a context where explicit verbal cues are not provided, requires that a speaker first detects and recognizes the meaning behind a listener's facial expression. Thus, we would expect that children's ability to identify the need to repair messages and decide to repair messages based on affective cues would relate to their ability to recognize and understand the emotions of others (i.e., EK). Certainly, in contexts outside of communication, preschoolers' EK has predicted their response to others' emotional expressions (e.g., Denham 1986; Denham & Couchoud, 1991).

The Current Study

The first goal of the present study was to assess 4- and 5-year-old children's ability to use affective cues from a listener to guide their evaluation and repair of messages. We chose this age range due to the rapid growth in communicative ambiguity detection shown within this age range (Nilsen & Graham, 2012) and to be consistent with the literature showing the relations between EF and repairs following *verbal* feedback (e.g., Bacso & Nilsen, 2017; Wardlow & Heyman,

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2016). During the current study, children were asked to provide instructions to a (fictional) child listener about where to find a prize. Based on the quality of the children's initial messages, the listener either found the prize and looked happy, or failed to find the prize and looked sad. The listener's affective reaction was matched to the success of the trial to be consistent with how natural interactions unfold.

To capture children's performance on the three steps to the repair process, we asked them to provide perceptions of their communicative success through ratings (detecting miscommunication), decide whether they would like to repair or not (repair decision), and assessed their success at generating a revised statement (repair). We expected that children would demonstrate an ability to use the affective cues of the listener to guide their ratings and to guide their communicative behavior. The second goal was to examine the associations between children's EF and EK and their ability to detect and repair miscommunication. We anticipated that children's EF and EK would be associated with more accurate ratings of their initial statements and with more effective communicative behavior. That is, children with stronger EF and EK skills would be more accurate in determining the success of the trial and the quality of their message based on the affective cues provided by the listener compared to those children with lower EF and EK.

We also anticipated that children's EF would be associated with higher quality of initial messages, and higher quality of repair statements, as has been shown in past research. Given that past research has shown that children learn from feedback over time (e.g., Bacso & Nilsen, 2017; Wardlow & Heyman, 2016), we also included the effect of trial in our models.

Method

Participants

Participants were 101 children ($M_{age} = 5.10$ years; $SD = 0.53$ years; 47 females) ranging in age from 4;0 to 5;11 recruited from elementary schools in a mid-sized Canadian city. The majority of children in the sample spoke English from birth (98%), and 19% of participants spoke another language other than English at home regularly.

The original sample was 109 children. However, data from participants who did not attempt to identify the target during the communication task on 3 or more trials (e.g., instead naming an alternate object to the target; $n = 5$) and from three participants who discontinued their participation partway through the communication task ($n = 3$) were not included in the analyses. Thus, a total of 8 participants were excluded from analyses.

Procedure and Materials

Participants completed tasks in the order listed below.

Communication Task

Task Setup. Participants sat at a table across from a computer screen which showed the pre-recorded videos of another child of similar age (the listener, “Anne”) in seemingly live display. The experimenter sat beside the participant and discretely controlled which videos were played using a Bluetooth keyboard.

Warm-Up Procedures. Participants played a warm-up game with the listener on the computer screen. During this game, the experimenter told the participant that the child on the computer screen can hear them but cannot see them. The experimenter gave the child a picture of an object (a banana) and told the participant to give specific clues to the child on the computer screen in order for them to guess what the object is. For example, the experimenter asked participants what color the object was and, after the participants said “yellow”, the experimenter

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played a pre-recorded video of the listener asking, "is it a lemon?" After participants provided three clues about the object to the child on the screen, a video was played of the child on the screen correctly guessing the object. This warm-up game demonstrated to participants that the listener on the computer screen could hear them and could respond to their messages but could not see the images in front of the participants.

Practice Trials. Children completed three practice trials. For practice trials, children were given a card depicting four boxes with different pictures on them (e.g., a flower, a sun, a cloud, and a tree). Children were told they would be helping the listener to find prizes. They were told that the listener has the same boxes in front of her as those shown on the child's card, and that the prizes were hidden in different boxes. The video panned across the boxes in front of the listener to show children that they were the same as those shown on their card, but in a different order. Participants were reminded that the listener can hear them but cannot see them so they would have to use their words to indicate which box the prize is hidden inside. The experimenter told the child, "It's in this one", and placed a token beside the picture of the target box. The child then told the listener which box the prize was inside. For practice trials, the boxes all had different pictures, so only the name of the picture was required to uniquely identify the target box (e.g., "the one with the sun on it"). Once the child provided an effective message, a video played of the listener picking up the target box and finding a candy inside.

Test Trials. During test trials, children were again asked to describe which box the prize was located in for the listener (see Appendix A for a flow chart of test trial procedures). The experimenter showed the child which box the prize was hidden in by placing a token (which corresponded to boxes in front of the listener, albeit in a scrambled order). Contrary to practice trials, they were told that during test trials they would not be shown which box the listener chose.

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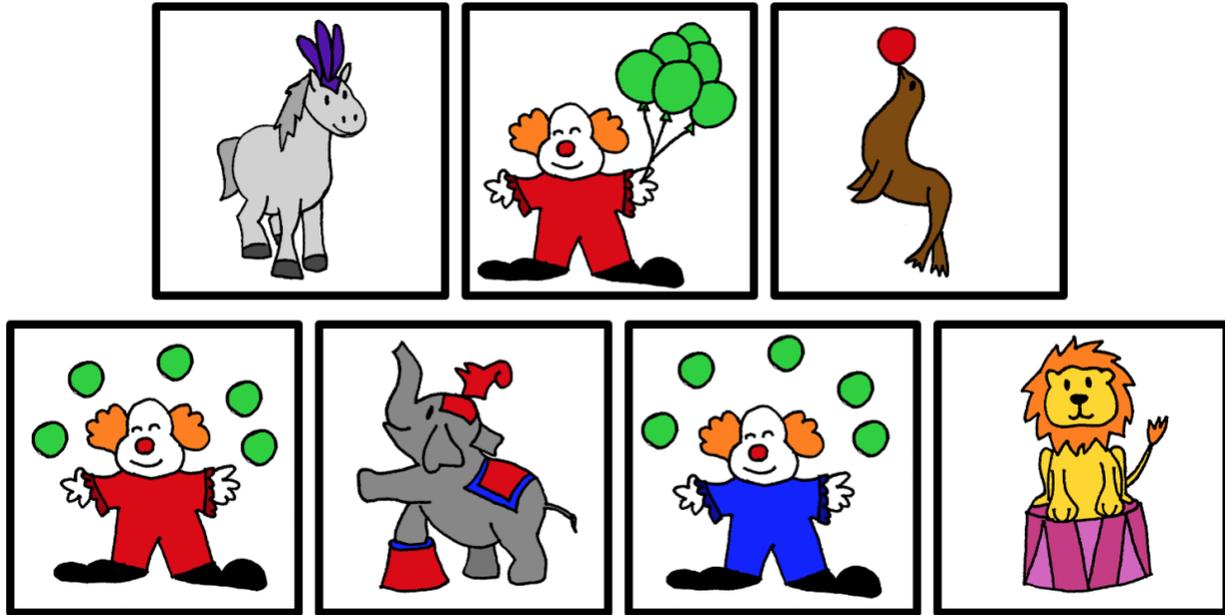
Children were also told that they could have another chance to tell the listener which box to choose if they wished to.

On each trial children were given a card depicting the images shown on the listener's boxes (see Figure 1). There were two different types of trials, which varied in the number of descriptors required to uniquely identify the target box (see Appendix B for specific items). Stimuli for complex trials were designed such that children were likely to provide an ambiguous message on their first attempt, whereas stimuli on simple trials were designed such that children were likely to provide a uniquely identifying message on their first attempt. On *complex trials*, the image on the target box (e.g., a red clown juggling) was similar to those shown on several distractor boxes (e.g., a blue clown juggling and a red clown holding balloons), but was varied on two dimensions (i.e., color, and associated object name). As such, to uniquely identify the target, two descriptors and the object name were required (e.g., "the one with the red clown juggling"). On *simple trials*, the image on the target box (e.g., a lion) was not similar to those shown on any of the other boxes (i.e., a clown, horse, etc.), and as such only the object name was required to uniquely identify the target (e.g., "the lion"). Thus, for complex trials, two descriptors were required to uniquely identify the target. On simple trials no descriptors were required. Children completed a total of 10 test trials (5 complex and 5 simple) in pseudorandom order. Once the child provided their initial message, a video was shown of the listener reaching for a box, and her reaction to the box she opened. Children were not able to see which box was opened. If the child's message was ambiguous, the listener chose a box and looked sad¹. If the child's message was

¹ As a manipulation check, we showed children 4 screenshots of the listener's face (from the communication task) appearing happy and sad and asked them to identify whether the listener appeared

Figure 1

Example of Stimuli Used for the Communication Tasks



Note. The child was told that the listener had boxes with the same cards printed on them. Each array had a total of 7 boxes, as shown here. For this set of stimuli, the complex target was the red clown juggling. The simple trial target was the lion.

happy or sad. Children were quite accurate in labeling the images with the correct emotion; 86% of children correctly identified the correct emotion on either 3 or 4 images. We also ran analyses excluding children who failed to correctly identify the correct emotion on 3 or 4 images. The pattern of results remained the same, with the exception that was no longer a significant interaction between executive functioning and facial cue in predicting speaker ratings (as presented in the Results section).

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uniquely identifying, the listener chose a box and looked happy. Regardless of the quality of the child's message on their first attempt, they were asked a series of questions about each trial by the experimenter after seeing the listener's facial expression:

I. Detection of miscommunication

- 1) *Do you think Anne found the prize this time?* **Success rating:** this determined the extent to which participants detected that miscommunication has occurred. Possible responses included "1" (*yes*) or "0" (*no*).
- 2) *How well do you think you described the box?* **Self rating:** this determined participants' ability to evaluate their own message. Children responded on scale from "-1" (*Not well*), "0" (*Okay*), and "1" (*Well*).
- 3) *How well did Anne do at listening?* **Listener rating:** this question was used to determine whether participants attribute the success or failure of communication to the skills of the listener. They responded on a scale from "-1" (*Not well*), "0" (*Okay*), and "1" (*Well*),

II. Decision to repair

- 4) *Do you think you should try again?* [if yes] *Go ahead.* **Decision to repair:** this question was intended to determine whether children felt they should repair their initial message or not.

III. Repair behavior

- 5) If they chose to repair, the number of new descriptors and irrelevant descriptors provided was recorded.

Coding of Communicative Behavior. Children's initial messages and their attempts to repair their messages were coded by a research assistant unaware of the research hypotheses. The responses were coded for the following: *Object name* (the name of the target object, e.g., "the

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boy”); *number of descriptors* (the number of descriptors provided during children's initial responses, e.g., “the boy in the *red shirt*, holding *ice cream*” would count as 2 descriptors); *irrelevant descriptors* (the number of descriptors provided during children's initial response or during repairs which do not include identifying information about the target, e.g., “the boy with *black shoes*”, when all characters have black shoes); *new descriptors* (the number of new informative descriptors provided during a repair attempt that were not also included during the participants' initial response). Only number of descriptors and number of new descriptors were used for analyses.

A second research assistant coded the behaviors of 15 (15% of the total sample) randomly chosen participants to ensure reliability in coding. Interrater reliability for all coded responses was excellent (i.e., 99% agreement for the number of descriptors provided in initial statements and 96% agreement for the number of new descriptors following feedback).

Individual Difference Measures

Executive Functioning (EF). Children's EF was captured by a latent variable of children's performance on tasks of working memory, cognitive flexibility, and inhibitory control (described further in Results).

Inhibitory Control. Children's inhibitory control was assessed using the naming and inhibition tasks from the NEPSY-II (Korkman & Kirk, 2007); though, due to time constraints, only one (rather than two) trials of each were used. Children completed a practice trial, followed by a naming trial, and an inhibition trial. During the naming and inhibition trials, children were presented with a page showing 40 arrows arranged in rows and were asked to label the images as quickly as they could. On naming trials, children labelled shapes on a page (e.g., saying arrows are pointing “up” or “down”). After, children completed an inhibition trial, described similarly to the naming trials, however, children were asked to provide an incongruent label for the images

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(e.g., when they see an up arrow, they are asked to say “down”). This requires the child to inhibit their natural inclination to provide the correct label for the shape. The residual change score of the number of errors children made on the inhibition trial compared to the number of errors on the naming trial was used for analyses (max 40 errors for each trial). This provides a measure of children's inhibition skills while controlling for their naming skills. This change score was reflected (i.e., multiplied by -1), such that higher scores represented stronger inhibitory control skills (to be consistent with the other EF measures).

Cognitive Flexibility. To assess children's cognitive flexibility, the Object Classification Task for Children (OCTC; Smidts et al., 2004) was used. During the task, children sort a series of objects which can be sorted based on size, function, or color (i.e., a small yellow plane, small red plane, large red plane, large red car, large yellow car, and small yellow car). Participants first sorted these objects into two groups in as many ways as they could. The experimenter then asked them to label their sorting criteria. Children received three points for each correct sort, and an additional point for accurately labelling their sorting criteria. If children were unable to sort the objects based on color, size, and function, the experimenter sorted the objects into the groupings that were missed and asked the child to label the sort criteria. In this case, children received 2 points for correctly labelling each sort. If children were unable to correctly name the sort using this procedure, the experimenter then asked them to sort the objects based on the criteria that were missed. With this procedure, children received 1 point for each correct sort based on instructions by the experimenter. Total scores could range from 0 to 12.

Working Memory. Children's working memory was assessed using the Digit Span subtest from the Wechsler Intelligence Scale for Children—Fourth Edition (Wechsler, 2003) as a measure of verbal working memory. Children first completed the digit span forwards task, in which they are asked to repeat back a series of digits read out loud by the experimenter. They then completed

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the digit span backwards task, where they were required to repeat a series of digits read by the experimenter in a backwards order. Children received a total score combining forwards and backwards tasks, out of a maximum possible score of 32.

EF Task Reliability. The reliability for digit span and the inhibition task was available in the test manuals and was high for both tasks. For instance, the digit span task split-half reliability was $r = .86$ (6-year-olds), and the test-retest reliability was $r = .83$ (6-year-olds to 11-year-olds; Weschler, 2003). Note that, since the WISC-IV is not intended for use with the age-range of our sample, reliability data was not available for 4- or 5-year-olds. The inhibition task had a split-half reliability of $r = .96$ (5-year-olds), and a test-retest reliability of $r = .74$ (ages 5-6; Korkman & Kirk, 2007). Note that the reliability of the inhibition task may differ in the present study, since we only administered one of the usual two items. Reliability scores for the OCTC were not available.

Emotion Knowledge (EK). To capture two aspects of children's EK (emotion labelling and emotion understanding), we combined the scores from the emotion labelling and emotion understanding tasks to create an EK composite.

Emotion Labelling. Participants' emotion labelling was assessed using the Expressions subtest from the Assessment of Children's Emotion Skills (ACES; Schultz et al., 2004). During the ACES, children saw 16 photographs of children displaying various emotions that they had to label as happy, sad, mad, or scared.

Emotion Understanding. Participants' emotion understanding was assessed using the Emotion Recognition Questionnaire (ERQ; Ribordy et al., 1988). This task assesses children's knowledge about different situations that elicit various emotions in others. During the task, children heard 12 (from the original 16) vignettes depicting a variety of situations and identified which emotion the main character was feeling out of three options provided by the experimenter.

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Expressive Vocabulary. Expressive vocabulary scores were assessed for use as a control measure using the Picture Naming task from the Wechsler Preschool and Primary Scale of Intelligence—Third Edition (Wechsler, 2002). For this task, children named a series of pictures that were presented to them. Children's raw scores (/24) were used for analyses.

Results

Preliminary Analyses

Two participants' scores were outliers for the number of errors on the inhibition task. Their scores on this measure were Winsorized to be within 3 standard deviations of the mean (as per Tabachnick & Fidell, 2007). For all continuous variables used in analyses, the standardized residuals of regression analyses showed normal distributions. Independent variables included in analyses also showed acceptable ranges for regression analyses (OCTC min = 4, max = 12; Digit span total score min = 3, max = 15; Inhibition total errors min = 0, max = 21; ACES min = 6, max = 16; ERQ min = 4, max = 12).

Skewness and kurtosis were also assessed for variables used to model executive functioning (OCTC skewness = 0.07, kurtosis = -1.24; Digit span total score skewness = -0.77, kurtosis = 0.59; Inhibition residual score skewness = -0.77, kurtosis = 0.60). Shapiro-Wilk tests were performed and found that the distributions of each variable departed significantly from normality (OCTC: $W = 0.90, p < .001$; Digit span total score: $W = 0.96, p < .001$; Inhibition residual score: $W = 0.94, p < .001$). However, all values for skewness and kurtosis fell within the acceptable ranges for normally distributed data (skewness and kurtosis between -1.5 and 1.5; Tabachnick & Fidell, 2013). Other researchers have noted that problems with non-normally distributed data generally start to arise when skewness is greater than 2 and kurtosis is greater than 7 (Curran et al., 1996). In addition, variables used to model executive functioning were

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assessed for multivariate outliers based on Mahalanobis' distance scores. No multivariate outliers were identified based on a cut-off probability score of $p < .001$ ($ps > .02$).

Model of Executive Functioning

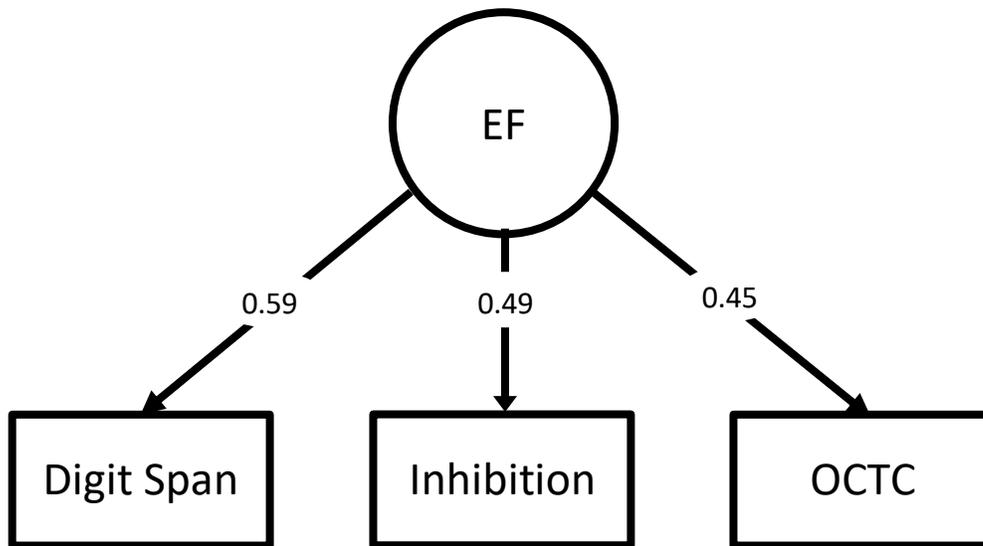
A measurement model of an EF latent variable was created using children's digit span, OCTC scores, and reflected residual change scores on the inhibition task (see Figure 2 and Table 1). Analyses were conducted with the Lavaan package in R using maximum likelihood estimation (R Core Team, 2013). The variance of the EF factor was set to 1. Indicators were allowed to covary within the model. As a result, the model had 0 degrees of freedom and model fit could not be assessed. Since factor loadings of each EF task onto the EF factor were statistically significant, the EF latent variable was used for all further analyses.

Methods for Analyses

To examine whether children were sensitive to the listener's affective cues when evaluating their own messages and repairing miscommunication, as well as the skills that relate to their behavior, we created several mixed models. Data were analyzed using multilevel modeling due to the hierarchical nature of our data (i.e., level one data would be the trials completed by participants, where level two data would be different participants). Multilevel modeling allows for residual components for each level of this hierarchy, thus controlling for idiosyncratic differences across trials within participants, and across participants. Multilevel models also are better equipped to deal with missing data compared to more traditional analyses. Models were created using the *lmer()* function and *glm()* function of the lme4 package (Bates et al., 2013) in R. Linear models (LMs) were used for numerical outcome variables; however, some of the outcome variables in this study were binary (e.g., success ratings and the decision to repair statements, with values of 1/yes or 0/no), and as such did not follow a normal distribution. Binary data was analyzed using generalized linear models (GLMs) which allow for dependent variables with

Figure 2

Associations of the Latent Executive Functioning Variable with Executive Functioning Tasks



Note. Beta (β) weights are shown in this model. The variables included were the digit span forwards and backwards total score, the reflected residual change score of the number of errors on the inhibition task, and the total score of the Object Classification Task for Children (OCTC). Associations between the digit span task, inhibition task, and OCTC task with the executive functioning latent variable were statistically significant ($p < .01$).

Table 1

Factor Loadings, Standard Error, Z-Values, and p-Values for Indicators of the Executive Functioning Latent Variable.

Indicator	β	<i>B</i>	<i>SE</i>	<i>Z</i>	<i>p-value</i>
Digit Span	0.59	1.62	0.49	3.34	.001
Inhibition	0.49	2.17	0.71	3.06	.002
OCTC	0.45	1.01	0.34	3.02	.003

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binary data. All base models included random intercepts for participant as well as a fixed effect for trial. The fixed effect for trial was included as a control variable. Random slopes models were compared to these random intercept models to determine which provided the best fit. In most cases, random intercept models provided better fit than random slopes models, so these were used for analyses. When the random slopes models were used below, it is noted. To examine the effect of each variable, we added each variable to the model and compared the model fit to that of the base model. Models that did not result in significantly improved model fit were not examined further.

Throughout the analyses, the role of EF and EK were assessed separately since these variables were correlated ($r = 0.25, p < .01$) and research questions did not involve looking at the relationship between one of these variables and children's communicative behaviour while controlling for the other. Rather, we wanted to see the influence of both factors of executive functioning and emotion knowledge on children's communication behavior. Because the two variables are correlated, putting them both in a model together had the potential to mask the effect of the other variable, which may limit our ability to capture the relationship that each EF and EK share with children's communicative behavior if included in the same model.

Correlations between outcome variables when both sad and happy faces were presented can be found in Table 2 (excluding the number of new descriptors added during repairs because this only applies to sad face trials). Correlations between age, expressive vocabulary, and all outcome variables when a sad face was presented (i.e., repair needed) can be found in Table 3.

Models including covariates (age, gender, school attended, and expressive vocabulary) in addition to the variables of interest were compared with models which did not include covariates throughout the analyses in order to control for the influence of other possible characteristics of

participants. In all cases, models including covariates did not demonstrate better fit than models without covariates, thus we report models without covariates.

The results in the following sections use data from both the complex and simple trials. Since we designed the task to elicit miscommunication, such that children infrequently provided a uniquely identifying message on initial attempts during complex trials, some children only saw the listener look happy during a simple trial².

Detecting Miscommunication: Children's Judgments of Messages

Children's perceptions of their messages reflect the first stage of the repair process, in which children are required to first identify that their communication is in need of repair. We fit six mixed-effects models using the variables that provided information about children's perceptions of their own messages based on the nonverbal cues provided by the listener. There were two models for each dependent variable of success ratings, self ratings, and listener ratings. For each of these models, the base models were the same and included the within-participants predictor of trial, with random intercepts included for participants. Fixed effects for facial cue, EF and EK were added to the models. As mentioned, we examined EF and EK in separate models.

Success Ratings

Recall that success ratings refer to children's judgements as to whether or not the listener found the prize on each trial. For success ratings, a one-way ANOVA revealed that the model

² To ensure that children were not solely using trial complexity as a cue about the quality of their message, we also re-analyzed the data using only data from the complex trials and found that the pattern of results was identical. This suggests that children were not only using the complexity of the stimuli as a cue to guide their ratings and decision to repair their messages.

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Table 2

Means, Standard Deviations, Odds Ratios and Multilevel Correlations with Confidence Intervals Between Communication Task Measures for All Data

Variable	<i>M</i>	<i>SD</i>	1	2	3	4
Detection of miscommunication						
1. Success rating ¹	0.60	0.49				
2. Speaker rating	0.20	0.83	7.25** [5.07, 10.36]			
3. Listener rating	0.34	0.78	4.91** [3.53, 6.83]	.43** [.36, .50]		
4. Descriptors in initial messages	0.61	0.68	11.79** [4.69, 29.61]	.23** [.12, .35]	.13* [.01, .24]	
5. Repair decision ¹	0.61	0.49	0.24** [0.24, 0.24]	0.45** [0.33, 0.61]	0.41** [0.29, 0.59]	0.73 [0.42, 1.26]

Note. *M* and *SD* are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. The confidence interval is a plausible range of population correlations that could have caused the sample correlation. Success ratings refer to children's judgments on whether or not the trial was successful (i.e., whether or not she found the prize). This table includes data from all trials, i.e., both trials where the listener appears happy and trials where the listener appears sad. Note that the number of new descriptors provided during repairs were not included in this table, as the correlations between these and other variables are difficult to interpret when data from both happy and sad trials are included. The number of new descriptors provided during repairs can be seen in Table 3. * indicates $p < .05$. ** indicates $p < .01$

¹ Odds ratios are reported rather than correlation coefficients given that success ratings and repair decision were binary outcome variables.

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Table 3

Means, Standard Deviations, Correlations, and Odds Ratios with Confidence Intervals for Trials where a Sad Face was Shown (i.e., Repair Needed)

Variable	<i>M</i>	<i>SD</i>	1	2	3	4	5	6	7
1. Age	5.11	0.53							
2. Picture Naming	19.43	3.57	-.02 [-.22, .19]						
3. EF	0.00	0.70	.35** [.16, .51]	.07 [-.13, .27]					
4. EK	-0.03	1.03	.31** [.11, .48]	.24* [.05, .42]	.31** [.12, .48]				
Detection of miscommunication									
5. Success rating ¹	0.31	0.46	0.37* [0.17, 0.80]	0.66 [0.32, 1.34]	0.56 [0.21, 1.51]	0.50 [0.25, 1.01]			
6. Speaker rating ²	-0.10	0.84	-.02 [-.18, .14]	.11 [-.05, .27]	.13 [-.03, .28]	.02 [-.13, .18]	9.48** [4.31, 20.86]		
7. Listener rating ²	0.12	0.81	-.07 [-.23, .09]	.00 [-.16, .16]	.13 [-.03, .29]	-.02 [-.17, .14]	7.55** [7.54, 7.57]	.37** [.26, .48]	
8. Repair decision ¹	0.70	0.46	1.80* [0.08, 1.10]	1.77* [1.08, 2.93]	1.07 [0.53, 2.13]	2.16** [1.31, 3.57]	0.22* [0.07, 0.64]	0.50** [0.29, 0.84]	0.55* [0.32, 0.95]
9. Repairs: New descriptors ²	0.25	0.47	.16 [-.01, .33]	.10 [-.07, .27]	.08 [-.09, .25]	.05 [-.12, .22]	0.05 [0.00, 3.06]	.08 [-.07, .24]	-.10 [-.26, .05]

Note. *M* and *SD* are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. The confidence interval is a plausible range of population correlations that could have caused the sample correlation. This table includes only data from trials where a sad face was shown (i.e., the trial was unsuccessful). * indicates $p < .05$. ** indicates $p < .01$.

¹ Multilevel odds ratios are reported rather than correlation coefficients given that success ratings and repair decision were binary outcome variables.

² Correlations are multilevel correlations.

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including facial cue fit significantly better than the base model, $\chi^2(1, n = 593) = 198.33, p < .001$, suggesting a significant main effect of facial cue. This main effect is elaborated on in the analyses described below. Adding the latent variable of EF to the model that included facial expression, trial, and the random effect of participant did not improve model fit ($\chi^2(1, n = 587) = 0.01, p = .59$), which suggests there was no main effect of EF. However, adding an interaction term of EF and facial cue significantly improved model fit, $\chi^2(2, n = 587) = 11.58, p = .003$. Thus, we used this model to assess the findings (See Table 4, Model 1).

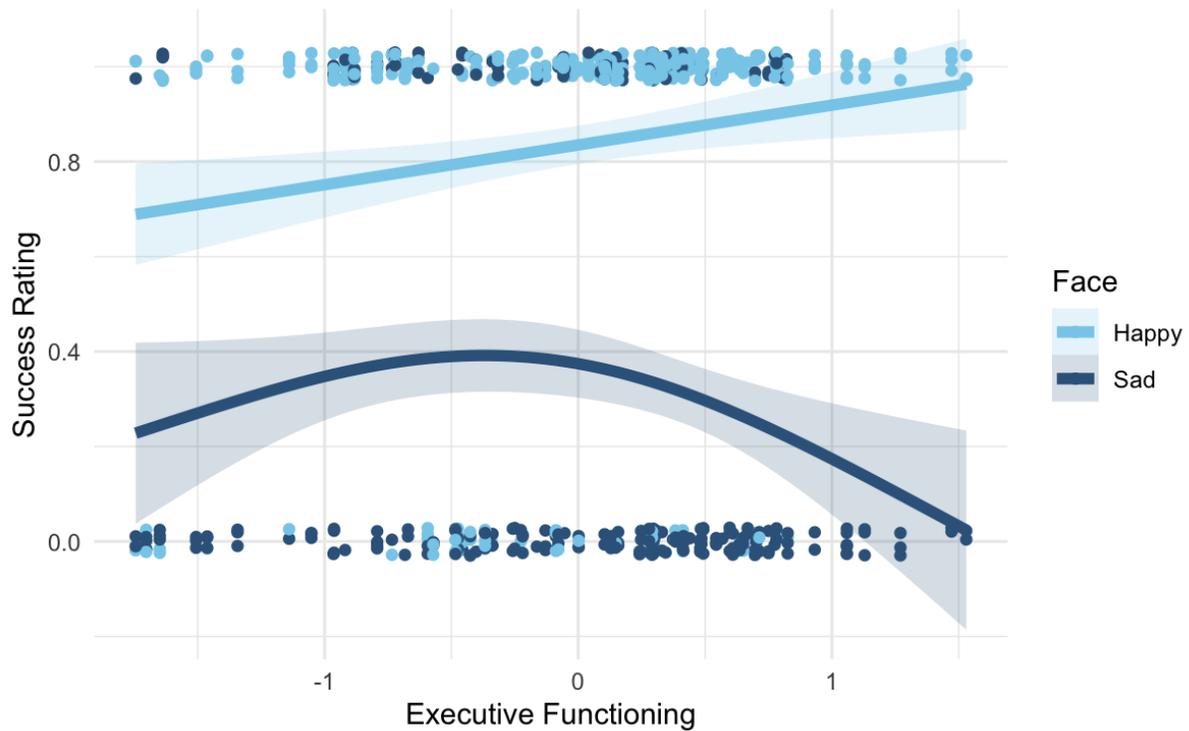
Analyses revealed a significant main effect of facial cue, such that participants were more likely to rate the trial as successful following seeing the listener look happy ($M = 0.84, SE = 0.02$), compared to after seeing her look sad ($M = 0.31, SE = 0.03$). There was also a significant main effect of trial, where participants were more likely to rate the trial as successful on later trials, suggesting learning across trials. A significant interaction between facial cue and EF emerged and indicated that children with high EF were more likely to rate the trial as successful following seeing the listener look happy compared to those with weak EF skills (see Figure 3a). When the listener appeared sad, children with high EF were more likely to rate the trial as unsuccessful compared to those with weak EF. Therefore, children with high EF skills provided more accurate ratings of trial success based on the listener's facial cues. When the interaction was included in the model, there was also a significant main effect of EF such that children with stronger EF were more likely to rate the trial as successful overall compared to those with weaker EF.

Adding the composite variable of EK (i.e., instead of EF) to the model including facial cue did not result in improved model fit ($p = .96$). Adding the interaction term to the model significantly improved model fit, $\chi^2(2, n = 563) = 18.01, p < .001$. The model revealed a

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Figure 3a

Children's Likelihood of Rating a Trial as Being Successful in Relation to the Listener's Facial Expression and to their Executive Functioning Skills

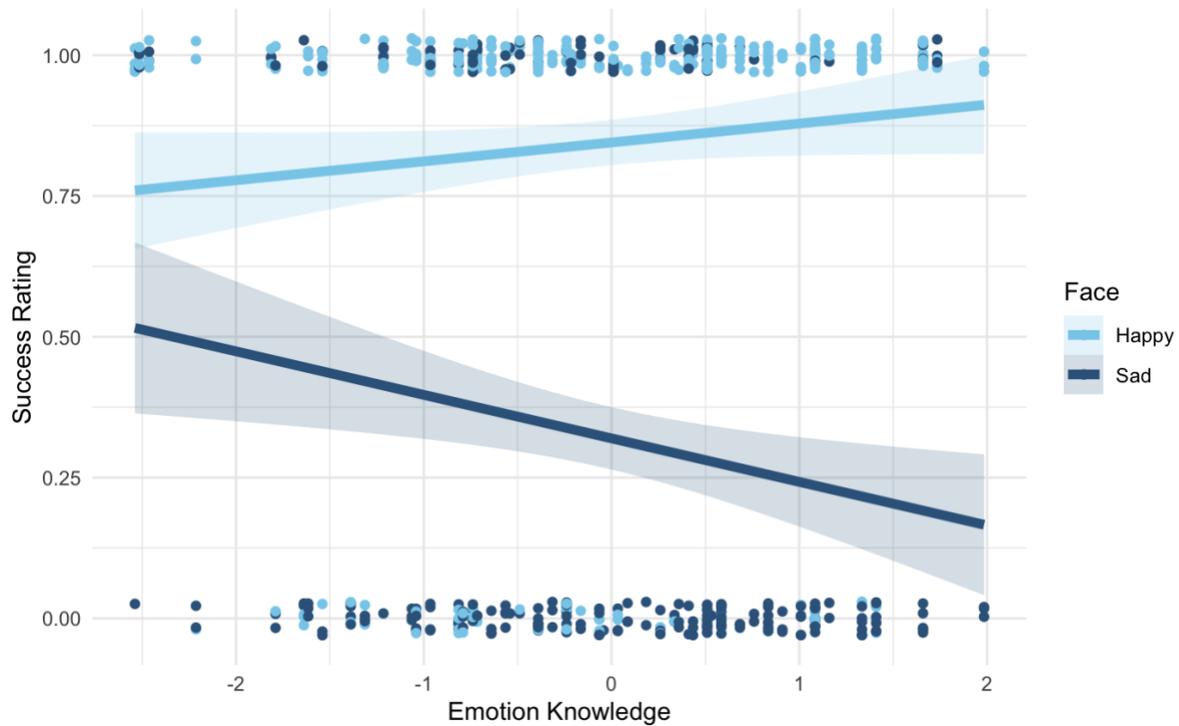


Note. Points represent children's ratings on each trial as being successful (1) or unsuccessful (0), while lines represent the average ratings of children at each level of executive functioning skills. From this panel, one can see that children with stronger executive functioning are better at discriminating whether or not a trial was successful based on whether a sad or happy face was shown. Children with strong executive functioning appear better able to determine that the trial was unsuccessful when a sad face was shown.

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Figure 3b

Children's Likelihood of Rating a Trial as Being Successful in Relation to the Listener's Facial Expression and to their Emotion Knowledge Skills



Note. Points represent children's ratings on each trial as being successful (1) or unsuccessful (0), while lines represent the average ratings of children at each level of emotion knowledge skills. From this panel, one can see that children with stronger emotion knowledge are better at discriminating whether or not a trial was successful based on whether a sad or happy face was shown.

Table 4

Details of the Best-Fitting Mixed-Effects Models for Success Ratings

Model	Fixed Effects			
Model 1 Executive Functioning	Facial Cue + EF + Facial Cue*EF + Trial			
	Predictors:			
		β	95% CI	p
	Facial Cue	-4.08	[-4.90, -3.26]	<.001
	EF	1.31	[0.11, 2.50]	.03
	Facial Cue*EF	-1.36	[-2.17, -0.56]	.001
	Trial	0.61	[0.07, 1.16]	.03
Model 2 Emotion knowledge	Facial Cue + EK + Facial Cue*EK + Trial			
	Predictors:			
		β	95% CI	p
	Facial Cue	-4.51	[-5.47, -3.56]	<.001
	EK	1.57	[0.19, 2.94]	.03
	Facial Cue*EK	-1.96	[-2.94, -0.97]	<.001
	Trial	0.77	[0.18, 1.35]	.01

significant main effect of facial cue (see Table 4, Model 2), EK, and trial, as well as a significant interaction between facial cue and EK (see Figure 3b). This interaction suggested that children with higher EK skills were better able to detect whether or not the trial was successful based on the listener’s facial expressions. For instance, children with higher EK were more likely to rate the trial as unsuccessful when the listener appeared sad, and successful when the listener appeared happy, compared to those with weak EK. Interestingly, a main effect of EK emerged within this model which indicated that children with higher EK were more likely to rate the trial as being successful than those with low EK, regardless of the facial expression of the listener. Overall, for success ratings, we found that children were more likely to rate the trial as successful following seeing the listener look happy, compared to after seeing her look sad, with children who have higher skills in either EF or EK being more accurate at these determinations.

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Self Ratings

When examining children's ratings of their own skill, a one-way ANOVA revealed that the model including facial cue fit significantly better, $\chi^2(1, n = 593) = 62.91, p < .001$, suggesting a significant main effect of facial cue. We discuss this main effect within the models below.

Adding the latent variable of EF to the model including facial cue significantly improved model fit, $\chi^2(1, n = 564) = 11.87, p = .001$, which suggests there was a main effect of EF. Children with stronger EF were more likely to give their own performance as a speaker a higher rating than those with weaker EF, regardless of the facial expression of the listener. Adding an interaction term of EF and facial cue to this model significantly improved model fit, $\chi^2(1, n = 587) = 4.60, p = .03$. Within this model there was a significant main effect of facial cue (see Table 5, Model 1), such that participants rated their skills as a speaker higher on trials where the listener looked happy ($M = 0.43, SE = 0.041$), and lower after seeing her look sad ($M = -0.09, SE = 0.052$). There was no significant main effect of trial. A significant interaction between facial cue and EF indicated that children with high EF were more likely to rate their skills as speakers higher following seeing the listener looking happy compared to those with weak EF skills. When the listener appeared sad, children with high EF were more likely to rate their skills as speakers on each trial lower compared to those with weaker EF. Therefore, children with high EF skills provided more accurate ratings of their skills as speakers based on the listener's facial cues.

When EK was added to the model that included facial cue, it resulted in improved model fit, $\chi^2(1, n = 587) = 4.44, p = .04$. This indicates a significant main effect of EK, where children with stronger EK were more likely to rate their performance as a speaker higher than those with weaker EK. Adding the interaction term to the model significantly improved model fit, $\chi^2(1, n =$

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563) = 9.81, $p = .002$. The model revealed a significant main effect of facial cue and EK (see Table 5, Model 2), as well as a significant interaction between facial cue and EK. This interaction suggested that children with higher EK skills were better at recognizing that they had provided a good description of the target when the listener appeared happy, compared to those with weak EK skills. When the listener’s facial expression was sad, children all provided low self ratings, regardless of their EK skills.

Thus, we see that, again, children appear to be able to use the listener’s facial cues to guide their perceptions of their communication, and that children with stronger EF and EK skills are more accurate in their judgments.

Table 5

Details of the Best-Fitting Mixed-Effects Models for Self Ratings

Model	Fixed Effects			
Model 1 Executive Functioning	Facial Cue + EF + Facial Cue*EF + Trial			
	Predictors:			
		β	95% CI	p
	Facial Cue	-0.31	[-0.38, -0.23]	<.001
	EF	0.27	[0.14, 0.40]	<.001
	Facial Cue*EF	-0.11	[-0.20, -0.01]	.03
	Trial	0.01	[0.06, 0.08]	.75
Model 2 Emotion knowledge	Facial Cue + EK + Facial Cue*EK + Trial			
	Predictors:			
		β	95% CI	p
	Facial Cue	-0.31	[-0.38, -0.24]	<.001
	EK	0.22	[0.09, 0.35]	.001
	Facial Cue*EK	-0.15	[-0.25, -0.06]	.001
	Trial	0.01	[-0.06, 0.08]	.73

Listener Ratings

To investigate children's listener ratings, we fit a mixed-effects regression model including the within-participants predictor of trial, with random intercepts included for participants. For this model, the dependent variable was children's ratings of the listener's performance on each trial.

Facial cue was added as a fixed effect to the model to assess the impact of the listener's facial expressions on children's ratings of the listener's performance. A one-way ANOVA revealed that the model including facial cue fit significantly better, $\chi^2(1, n = 593) = 37.56, p < .001$, suggesting a significant main effect of facial cue. This main effect is elaborated on in the analyses described below.

Adding the latent variable of EF to the model including facial expression significantly improved model fit, $\chi^2(1, n = 564) = 43.91, p < 0.01$, which suggests there was a main effect of EF. However, there was no significant interaction between EF and facial cue. Analyses revealed a significant main effect of facial cue (see Table 6, Model 1), such that participants rated the listener higher following seeing the listener look happy ($M = 0.52, SE = 0.04$), and lower after seeing her look sad ($M = 0.12, SE = 0.05$). There was no significant main effect of trial. There was a significant main effect of EF, which indicated that children with stronger EF were more likely to give the listener a higher rating than those with weaker EF, regardless of the facial expression of the listener. This suggests that children with stronger EF were more accurate in their ratings of the listener since the listener always followed their instructions perfectly (i.e., the listener always found the prize if the speaker gave an accurate description of the correct box).

Table 6

Details of the Best-Fitting Mixed-Effects Models for Listener Ratings

Model	Fixed Effects			
Model 1 Executive Functioning	Facial Cue + EF + Trial			
	Predictors:			
		β	95% CI	p
	Facial Cue	-0.26	[-0.33, -0.18]	<.001
	EF	0.15	[0.05, 0.25]	<.01
	Trial	0.004	[-0.07, 0.08]	.93
Model 2 Emotion knowledge	Facial Cue + EK + Facial Cue*EK + Trial			
	Predictors:			
		β	95% CI	p
	Facial Cue	-0.26	[-0.33, -0.18]	<.001
	EK	0.15	[0.03, 0.27]	.02
	Facial Cue*EK	-0.10	[-0.20, -0.05]	.04
	Trial	0.002	[-0.07, 0.08]	.95

Adding the composite variable of emotion knowledge (EK) to the model without including EF, did not result in improved model fit ($p = .06$). Adding the interaction term to the model significantly improved model fit, $\chi^2(2, n = 563) = 10.43, p = .005$. The model revealed a significant main effect of facial cue (see Table 6, Model 2), a significant main effect of EK, and a significant interaction between facial cue and EK. The main effect of EK and this interaction suggest that children with higher EK skills rated the listener higher than those with weaker EK skills, with this effect most apparent when the listener appeared happy. When the listener’s facial expression was sad, children’s ratings were lower, with EK skills having less of an impact on children’s ratings compared to when the listener appeared happy.

Overall, we see that as with speaker ratings, children’s listener ratings were higher when the listener appeared happy than when she appeared sad. We also found that children with higher EF and EK were more likely to rate the listener higher than those with low EF and EK, which suggests that they provided more accurate ratings of the listener.

Number of Initial Identifying Descriptors

So as to provide some context in appreciating children's *repair* behavior, we first looked at how well children did during their initial statements. We focused on complex trials because these were the only trials in which descriptors were needed. In their initial descriptions, children uniquely identified the target on 11% of complex trials (they uniquely identified the target on 100% of simple trials). They provided a mean of 0.61 descriptors on each complex trial, which means that on average, 1.39 descriptors needed to be added during repairs to uniquely identify the target.

As a secondary aim, we were interested in determining whether there were associations between EF/EK and children's quality of these initial messages (as determined by number of descriptors). For these analyses, data from the initial complex trials were used, as these were the only trials during which participants could provide identifying descriptors. Further, since children provided descriptors before they saw any facial cue from the listener, facial cue was not included in this set of models. A one-way ANOVA comparing the random intercept and random slopes models indicated that the random slopes model fit significantly better, $\chi^2(2, n = 281) = 11.56, p < .001$, so the random slopes model was used for all analyses involving this dependent variable. The dependent variable was the number of identifying descriptors provided by participants that were required to disambiguate the target box from distractors. The fixed effect of trial was included in the model as well as random slopes for participants' performance across trials. Within this model, there was a significant main effect of trial ($\beta = 0.24, 95\% \text{ CI } [0.14, 0.34], p < .001$), where participants provided more descriptors with each subsequent trial and a significant effect of age ($\beta = 0.24, 95\% \text{ CI } [0.09, 0.39], p = .002$), where older participants provided more identifying descriptors.

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Adding the latent variable of EF to the model including random slopes for participants' performance across trials, did not significantly improve model fit, which suggests there was no main effect of EF ($p = .13$). Adding the composite variable of EK to the model, without including EF, did not significantly improve model fit, which suggests there was no main effect of EK ($p = .15$).

Thus, we found that children who were older provided more identifying descriptors during their initial messages. We also saw that children's statements improved across trials, suggesting they learned from their mistakes to provide more accurate messages. There were no associations between children's EF or EK abilities and the number of identifying descriptors provided.

The Role of EF in Initial Descriptor Improvement across Trials

Given that children demonstrated improvement across trials as reflected by their providing more descriptors as the trials progressed, we were interested in assessing the role of EF in this possible learning. Thus, as a post-hoc analysis we looked at the interaction between EF and trial, to determine if children with stronger EF learned more quickly across trials. We found that there was no significant interaction between EF and trial ($p = .98$), suggesting that children all learned to provide more effective initial messages at similar rates, regardless of their EF skills.

Performance on Simple Trials

We were also interested in assessing the extent to which children modify their use of descriptors to identify targets based on the complexity of stimuli used. On simple trials, children frequently provided descriptors during their initial messages even though these were not required to uniquely identify the target (recall that only the object name was required to uniquely identify

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the target during simple trials). Children provided irrelevant descriptors on 38% of simple trials, which refers to descriptors that do not help to disambiguate the target from distractors. Children provided a mean of 0.65 irrelevant descriptors during simple trials (See Table 7). On complex trials, participants provided a mean of 0.92 descriptors in total, including both identifying descriptors and irrelevant descriptors. Thus, children were more informative during complex trials than during simple trials.

Children’s Decisions to Repair and Repair Success

To address our goal of examining children’s repair behavior, we looked at the next steps in the repair process (after detection), namely, their decision to repair, as well as their ability to provide necessary information (i.e., additional descriptors) to clarify misunderstood messages. The models for each analysis will be discussed in each section below.

Decision to Repair

After seeing a sad face, children attempted to repair their messages on 70% of trials. We fit a mixed-effects regression model with a dependent variable of children’s decision whether or not to repair their message on each trial. A one-way ANOVA comparing the random intercept and random slopes models indicated that the random slopes model fit significantly better, $\chi^2(2, n = 594) = 15.94, p < .001$, so the random slopes model was used for all analyses involving children’s decision whether or not to repair their message.

Table 7

Mean Number of Identifying Descriptors, Extra Descriptors, and Total Descriptors Across Complex and Simple Trials

Trial Type	Identifying Descriptors		Irrelevant Descriptors		Total Descriptors	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Simple	NA	NA	0.65	1.15	0.65	1.15
Complex	0.61	0.68	0.30	1.12	0.92	1.52

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Facial cue was added as a fixed effect to the model to assess the impact of the listener's facial expressions on children's decision to repair their initial message. A one-way ANOVA revealed that the model including facial cue fit significantly better, $\chi^2(1, n = 593) = 17.86, p < .001$, suggesting a significant main effect of facial cue. Children were more likely to repair their message following seeing the listener look sad ($M = 0.70, SE = 0.03$) than when the listener appeared happy ($M = 0.52, SE = 0.03$; see Table 7). A significant main effect of trial indicated that children were less likely to repair on each subsequent trial. This likely occurred because their initial descriptions significantly improved across trials, suggesting learning across trials, so there was less need to repair messages.

Adding the latent variable of EF to the model including facial expression did not significantly improve model fit, which suggests there was no main effect of EF ($p = .95$)³. Adding an interaction term between EF and facial cue also did not improve model fit, suggesting there was no interaction between EF and facial cue ($p = .56$).

Adding the composite variable of EK to the base model, did not result in improved model fit ($p = .09$). Adding the interaction term of EK and facial cue resulted in significantly better model fit, $\chi^2(2, n = 594) = 9.31, p = .01$. The model revealed a significant main effect of facial cue and trial, as well as a significant interaction between facial cue and EK (see Table 8). This interaction suggested that children with higher EK skills were better at recognizing that their message was in need of repair when the listener appeared sad. When the listener appeared happy, children's EK had less of an impact on their decision to repair. Thus, with respect to children's decisions about repairing their messages, we see that they are able to use the listener's facial cue to guide whether or not they should attempt to repair their message. We see that EK (but not EF)

³ Results did not differ when components of EF were examined separately (all $ps > .17$).

Table 8

Details of the Best-Fitting Mixed-Effects Models for the Decision to Repair

Fixed Effects			
Facial Cue + EK + Facial Cue*EK + Trial			
Significant Predictors:			
	β	95% CI	p
Facial Cue	1.02	[0.49, 1.54]	<.001
EK	0.34	[-0.74, 1.43]	.54
Facial Cue*EK	0.86	[0.18, 1.53]	.01
Trial	-1.30	[-1.83, -0.77]	<.001

is associated with children’s ability to initiate a repair based on the listener’s facial cues.

Repairs: Number of New Descriptors

The analyses below include only trials where children attempted to repair their messages following seeing a sad facial expression. While children were using the listener’s facial cue to guide repair attempts, their actual repairs were not very successful. That is, during repair attempts, children frequently repeated themselves (i.e., did so on 61% of attempts to repair initially ambiguous complex trials following seeing a sad facial expression). Children added new descriptors during repairs on 25% of trials. Overall, children provided a mean of 0.25 new descriptors on each initially ambiguous trial. Children successfully repaired their messages (i.e., provided all descriptors needed) on 15% of initially ambiguous complex trials⁴.

We found that participants provided fewer new descriptors with each subsequent trial ($\beta = -0.18$, 95% CI [-0.33, -0.26], $p < .001$). This is most likely due to participants providing more initial identifying descriptors on each trial, and thus being required to add fewer new descriptors during repairs. This provides further evidence of learning across trials.

⁴ Altogether, including successful responses during initial statements and repairs, participants were able to uniquely identify the target on 26% of complex trials.

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Adding the latent variable of EF to the model including the random effect of participant did not significantly improve model fit, which suggests there was no main effect of EF ($p = 0.33$)⁵. Adding the composite variable of emotion understanding also did not result in improved model fit ($p = .28$). This suggests there was no main effect of emotion understanding on the number of descriptors added by children during repairs.

In sum, when examining children's communicative behavior (i.e., decision to repair, new descriptors), we find that facial cues prompted more repair attempts, but the actual repair quality was relatively low within our task. This being said, children provided an increasing number of initial descriptors across trials, which suggests they were learning how to make their messages more effective throughout the task. Children with stronger EK were also more likely to attempt to repair their messages when the listener appeared sad.

Discussion

This study examined children's abilities in detecting miscommunication, deciding to repair, and repairing miscommunication, in a context where only affective cues from a listener were provided. Further, children's EF and EK skills in relation to these steps were examined.

Detecting Miscommunication: Children's Judgments of Messages

To assess children's recognition of miscommunication and determination of who may be at fault for this miscommunication, we asked children to rate whether or not they thought each trial was successful, their performance as speakers on each trial, and the listener's performance on each trial.

Findings supported our hypothesis that children had accurate perceptions of their communication in a context where they were only provided with affective cues. That is,

⁵ Results did not differ when components of EF were examined separately (all $ps > .35$)

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children's ratings across all areas indicated that they were able to detect whether or not the listener had found the prize on each trial based on the affective cues she provided. Specifically, children were more likely to rate the trial as being successful (i.e., the listener finding the prize) on trials where the listener appeared happy compared to trials where the listener looked sad. This finding is not surprising given past work which shows that even infants are able to understand that people's affective reactions should be consistent with the context (e.g., Chiarella & Poulin-Dubois, 2018). Importantly, in the present work, children were able to recognize their role in the success of each trial and rated their own performance as speakers as higher on trials where the listener appeared happy. This suggests that children show some degree of meta-communication, in that they are aware of their role in the success or failure of a communicative exchange. This being said, their listener ratings suggested that they adjusted their ratings of her skills based on the message success. Namely, children were likely to rate the listener as being less skilled following seeing her look sad compared to after seeing her look happy. Notably, the listener actually always responded in correspondence to what the child said (i.e., she always found the prize when children provided a uniquely identifying statement, and never found the prize following an ambiguous statement). So, really it was never the listener who was at fault when miscommunication occurred. Thus, children somewhat blamed the listener for their communicative errors (see Robinson & Robinson, 1983).

Together our results suggest that in a context where only affective cues are provided, preschool-age children show awareness of when miscommunication has occurred and, while they possess some insight as to their role in this, they do not take full responsibility for the miscommunication.

Communicative Repairs: Decision to Repair and Repair Success

We anticipated that children would be able to use affective cues to guide their decision to repair or not repair their messages. Children demonstrated some recognition as to what they should do when provided with affective cues that suggest miscommunication occurred: they were more likely to attempt to repair their messages in response to seeing the listener appear sad, compared to seeing the listener look happy. Thus, in addition to verbal feedback (Bacso & Nilsen, 2017), preschool-age children can detect when to correct misunderstandings when provided only with nonverbal cues from their communicative partners. Wardlow and Heyman (2016) similarly found that 5- and 6-year-olds improved their messages across trials in response to nonverbal feedback indicating that the child's message was misunderstood. Notably, Wardlow and Heyman's study included the listener making an incorrect object choice, which prevents conclusions about children's use of facial expressions for repairs. The present findings suggest, that in addition to recognizing that the trial was unsuccessful when the listener appeared sad, children also understood that the listener required more information and sometimes attempted to provide such information.

However, even though children detected communicative ambiguity, they often failed to resolve this ambiguity. That is, children were only able to successfully repair (i.e., provide all the necessary descriptors) their initially ambiguous messages on 15% of trials in which a repair was attempted. Instead, children frequently repeated themselves (on 61% of trials). This is consistent with past literature indicating that children tend to repeat their messages in response to vague feedback (Anselmi et al., 1986; Nilsen & Mangal, 2012). Thus, children had limited success in repairing their messages. As with other studies using verbal feedback (e.g., Bacso & Nilsen, 2017) it is likely that repairs using nonverbal feedback are a skill which improves across the

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school-age years. This pattern is similar to that shown in other studies (albeit not ones specifically involving repairs) wherein children may recognize the need to provide additional information but fail to produce it. For instance, within a referential communication task, even when 4-year-old children looked at distractor objects (same object as target, but differing in one dimension), they fail to provide effective messages (i.e., those that uniquely identify the target) for their listener 83% of the time (Davies & Kreysa, 2017).

Our findings that children were able to detect when miscommunication occurred based on nonverbal cues and attempted to repair their messages support the assertion by Rabagliati and Robertson (2017) that children may require an “error signal” to detect whether or not they have avoided ambiguity to guide their learning in production. In Rabagliati and Robertson’s study, children (ages 4 to 5) demonstrated some evidence of self-monitoring their own messages (i.e., they looked at a distractor object after producing a message for a listener) but did not attempt to repair messages after this self-monitoring. In our work, children were able to use the affective cues of the listener as a signal to determine that their message required clarification, and then attempted to clarify their messages. As in other studies which provided more specific cues indicating ambiguity had occurred (Bacso & Nilsen, 2017; Matthews et al., 2007; Matthews et al., 2012), children improved the clarity of their messages across trials. This suggests that they learned from miscommunication and from the error signal provided to adjust their production on subsequent trials. Thus, receiving affective cues and having the opportunity to repair their messages may be one way through which children’s skills as speakers improve.

Role of Executive Functioning and Emotion Knowledge in Detecting Miscommunication and Repair

The second goal of the study was to investigate associations between EF and EK with children's perceptions of miscommunication and repairs.

With respect to children's perceptions, findings indicated that children with strong EF skills more accurately assessed the communicative scenario. Specifically, children with strong EF were more likely to rate the trial as unsuccessful and rate their own performance lower following seeing the listener appear sad. When the listener appeared happy, children with strong EF were more likely to rate the trial as being successful and rate their performance as speakers higher. Children's EF skills were also associated with their ratings of the listener: Children with higher EF skills generally rated the listener higher, which was a more accurate appraisal as the listener always responded appropriately to children's descriptions of the target. Thus, it seems they were less likely to blame the listener for miscommunication.

In the present work, a latent variable captured an underlying EF construct across the different tasks. A latent variable approach was used in order to reduce the influence of measurement error and task-specific variance (Kaushanskaya et al., 2017; Tabachnick & Fidell, 2013). Further, existing studies support the use of a latent variable to measure EF in both adults (Miyake et al., 2000), and young children (Fuhs et al., 2014; Willoughby et al., 2012). With this construct in mind, it appears that children's general ability to monitor and control thought and action facilitates more accurate perceptions of message and interlocutor success. To further appreciate how EF may be contributing to children's message evaluation, it is useful to consider the various aspects required in determining effectiveness of communicative utterances. For instance, children must be able to hold in mind their statements while simultaneously considering

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a listener's feedback (in the present study, nonverbal feedback), likely relying on working memory (see Bacso & Nilsen, 2017; Wardlow, 2013; Wardlow & Heyman, 2016). Cognitive flexibility may have supported children's flexible attendance to the various features of the target object in relation to the other objects (e.g., notice that a boy wearing a red shirt is also holding ice cream) and, use this information to determine message (in)effectiveness and the need for repair (see Bacso & Nilsen, 2017 & Gillis & Nilsen, 2014). Lastly, children were required to consider the perspective of their listener when assessing the communicative scenario (her knowledge and affective state), which may have required them to shift attention away from considering their own perspective, potentially drawing on inhibitory control skills (see Wardlow, 2013).

Similar to EF, children with stronger EK were better able to assess the communicative situation: They provided more accurate ratings for success of the trial, their own skills as speakers, and the skills of the listener based on the affective feedback provided. For example, children with strong EK skills were likely to rate the trial as being unsuccessful and rate their skills as speakers lower on trials where the listener appeared sad. Like children with strong EF, children with strong EK skills were also more likely than those with weaker EK skills to rate the listener higher in general, with this effect being strongest when the listener appeared happy. This is similar to the role of EK in listener ratings in that children with strong EK appeared to provide more accurate ratings of the listener.

EK likely aided children in understanding the meaning behind the listener's emotions (i.e., not just that the listener was sad, but that the reason was that she did not find the prize). This appreciation would facilitate children's ability to make accurate success ratings, self ratings, and listener ratings. Children with stronger EK were also more likely to attempt to repair their

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messages after seeing the listener appear sad, suggesting that they had a greater appreciation for the fact that the listener needed additional information. These findings are important as they demonstrate that EK adds to the skills which have been shown to contribute to communicative success, such as EF and theory of mind (see Nilsen & Fecica, 2011). Further, they suggest that EK skills allow for more effective interactions with peers, which may account for the findings shown previously between EK and social skills (Bassett et al., 2012).

We found that EK, but not EF was associated with children's decision to repair their messages. Neither skill was associated with children's success in repairing their messages. We had anticipated that EF would be associated with children's decision to repair and their repair success based on past research which found that children's EF was associated with both the quality of their initial messages and the quality of repairs, albeit following verbal feedback (Bacso & Nilsen, 2017). Thus, it may be the case that EF skills are important in contexts where children can use verbal feedback to guide their repair behaviors. For instance, verbal feedback may place higher demands on executive skills than nonverbal feedback (e.g., children would need to hold the feedback in mind using working memory). However, the methodology of the present work may also account for different findings. In particular, in the present work, there was a time delay between children receiving the affective feedback and their opportunity to repair the message due to the questions asked. This may have interfered with the process of message repair that may have otherwise occurred, particularly for those children with high EF. For instance, it is possible that children with strong EF skills would have repaired their messages, if they would have had the immediate opportunity to do so, but the focus on answering questions disrupted this process.

Future Directions and Limitations

While this work provides insight into children's evaluation of messages and repairs, there are some limitations to note. One design aspect worth noting is that the listener's affective reaction to the child's message was always consistent with the quality of the message. That is, the listener always appeared sad after the child provided an ineffective message, and always appeared happy after an effective message. This decision was made so that the task was naturalistic, and the listener could be viewed as providing reliable cues. However, it is possible that children were gauging the success or failure of their messages by purely reflecting on their own messages in the absence of any cues from the listener. We feel this explanation is unlikely given that repairs do not happen in the absence of any cues and past work has shown that children rely on their communicative partners for information as to whether their message was successful or not (Anselmi et al., 1986; Nilsen & Mangal, 2012; Wardlow & Heyman, 2016). Moreover, the relation between EK and children's perceptions of their communication suggests that the affective information was being utilized. Alternatively, it is also possible that children decided to repair their messages based solely on the affective cues provided by the listener, without reflecting on the content of their initial messages. Further research is needed to more precisely understand how children integrate the various information they could use when repairing messages. In addition, the task was designed to be difficult for children, as we wanted them to provide initial messages that were ineffective so that we could capture repair behavior. However, given this, results should be interpreted within the demands of the task itself. A number of factors could influence the difficulty of referential communication tasks including the array size (our array included 7 items), the number of descriptors required for a uniquely identifying message, and the type of descriptors needed (i.e., some types of descriptors may be

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more readily produced by children, such as color or size; Nadig & Sedivy, 2002). In addition, the type of feedback provided by the listener has been shown to influence children's ability to uniquely identify target objects (i.e., detailed feedback resulting in more successful repairs; Bacso & Nilsen, 2017). In the present study, children's task was also made more difficult by the fact that they were required to provide two descriptors *in addition to* the object name in order to uniquely identify the target. Lastly, other variables that were not included in this study likely have an impact on children's repair behavior. For instance, children's level of shyness and/or their processing speed could have an impact on children's willingness/ability to repair messages. That is, children who are shy may be less willing to initiate a repair if they are hesitant to speak. Children with low processing speed may have had difficulty keeping up with the speed of the interaction, thus missing that a repair was required.

We also found that the relations between EF and EK with children's communicative behavior were quite similar. This suggests there may be a shared element that accounts for the similar pattern of data for EF and EK. One possibility is that Theory of Mind (ToM) accounts for the associations between EF and EK and is related to children's communicative behavior. Past research supports this idea since children's executive functioning skills relate to their ToM skills (e.g, Carlson & Moses, 2001; Carlson et al., 2002) and children's ToM skills also predict their emotion knowledge skills (Hughes & Dunn, 2002; Seidenfeld et al., 2014).

Given our findings, future research could explore whether children are able to spontaneously and immediately repair their messages in response to affective, nonverbal feedback, and examine whether EF and EK are associated with this skill. This would expand upon the present work, in which we assessed whether children would repair their message after they were asked to reflect on the message. That is, as noted above, this delay may have

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influenced their natural inclination to repair messages and muted any associations between EF and EK in the quality of their repairs. Future work assessing their tendency to repair immediately following a nonverbal cue would shed light on the role of EF and EK in children's ability to repair their messages and would likely fit more closely to how children interact with others in the real world. Future work could also assess whether children's EK is associated with other aspects of their communicative skills, such as their comprehension of other's messages (wherein affect cues are embedded, e.g., San Juan et al., 2017; Berman et al., 2010).

Overall, the findings add to the literature exploring children's use of various cues from listeners to correct miscommunication (e.g., Bacso & Nilsen, 2017; Coon et al., 1982; Deutsch & Pechmann, 1982; Nilsen & Mangal, 2012; Uzundag & Küntay, 2018). In particular, the present study finds that, in a context where only affective cues are provided by a listener, 4- and 5-year-old children are able to accurately perceive the success of their messages, and attempt repairs appropriately (albeit with limited repair success). Further, within this context, children with better EF and EK demonstrated more accurate evaluations of message success and the role that they and the listener played in such communicative outcomes.

**Study 2: Children's use of verbal and nonverbal feedback during communicative repair:
associations with executive functioning and emotion knowledge**

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Study 2 expands on Study 1 by investigating children's ability to immediately repair their messages in response to nonverbal feedback indicating they have been misunderstood (i.e., a confused facial expression). Whereas Study 1 looked at children's ability to determine whether their message was accurately understood by the listener based on the listener's affective response to their object selection, Study 2 assessed children's ability to respond to affective cues resulting from the statement (i.e., confusion). Also, where Study 1 assessed children's ability to detect miscommunication and provide repairs after reflecting on the quality of their messages, Study 2 assessed their ability to detect miscommunication and immediately repair their messages in real time. In addition, Study 2 investigated children's ability to use both verbal and nonverbal feedback. More specifically, the study assessed whether linguistic feedback (i.e., a confederate telling the child, "I don't know which one you mean"), affective feedback (i.e., a confused facial expression), or a combination of both is most effective in facilitating children's communication repair. I also assessed the role that individual differences in children's emotion knowledge and executive functioning skills play in their ability to repair their messages in response to linguistic and affective feedback.

Background

Children frequently fail to provide enough information for their listeners to effectively understand their communicative intentions (e.g., Deutsch & Pechmann, 1982, Lloyd et al., 1998). This makes their ability to identify this failure and repair miscommunication an essential aspect of their communicative development. Past work has demonstrated that children rely on feedback from their listener to support their communicative repairs (e.g., Bacso & Nilsen, 2017; Coon et al., 1982; Wardlow & Heyman, 2016). For instance, if a young child were trying to ask his mother for a specific ball, and there were three balls of varying size and color around her, he may request “the ball”. His mother would be left confused as to which ball he wanted, so likely would provide cues, such as a confused facial expression and a statement such as, “Which one?”. The boy then might repair his message, by saying, “the green one”, which provides his mother with enough information to identify the intended meaning behind his messages.

While past work has examined children's use of listeners' verbal feedback (Bacso & Nilsen, 2017; Coon et al., 1982; Deutsch & Pechmann, 1982; Nilsen & Mangal, 2013; Uzundag & Küntay, 2018) and, to a lesser extent, nonverbal feedback (Bacso et al., 2021), these cues have been examined separately, which means the relative support each of these channels provides for children remain unknown. As well, it is unclear how children's socio-cognitive skills are associated with repairs following feedback from these different communicative cues. The present study addressed these gaps, utilizing a referential communication paradigm wherein children (often) provided ambiguous instructions to a listener who then provided either verbal, nonverbal, or both verbal and nonverbal feedback indicating miscommunication. Thus, we were able to address the two key goals of examining the types of feedback children can utilize to repair their

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statements and determining whether executive functioning and/or emotion knowledge is associated with their repair behaviour.

The Role of Listener Feedback in Children's Communication

For a speaker to successfully repair miscommunication, they must identify that their initial message has been misunderstood, decide to attempt a repair, and generate a message that provides the information that corrects the misunderstanding (Bacso et al., 2021). These steps rely on feedback from a listener to guide a speaker in knowing when miscommunication has occurred and what information is needed. Past work on children's response to verbal feedback (reflecting the majority of work in this area) has found that 3- to 6-year-old children are able to repair their messages in response to listener statements indicating confusion or misunderstanding (e.g., Bacso & Nilsen, 2017; Coon et al., 1982; Deutsch & Pechmann, 1982; Nilsen & Mangal, 2013; Uzundag & Küntay, 2018). Further, 4- and 5-year-old children are better able to repair their messages when they receive detailed feedback indicating miscommunication has occurred (e.g., "there are three balls and I don't know which one you mean") compared to vague feedback (e.g., "I don't know which one you mean"; Bacso & Nilsen, 2017; Coon et al., 1982). When young children (ages 1 to 4) are provided with minimal feedback (e.g., huh, or what?) they tend to repeat their messages (Anselmi et al., 1986; Nilsen & Mangal, 2012). Receiving feedback from listeners and being provided with the opportunity to repair messages is thought to be an important way through which children become more effective communicators over time, in that they are better able to recognize the needs of their listener (Matthews et al., 2007), particularly when feedback is specific (Matthews et al., 2012).

The Role of Nonverbal Feedback in Children's Communication

While most research has explored children's ability to respond to verbal feedback indicating that miscommunication has occurred, some studies have explored the role of *nonverbal* feedback. Certainly, when interpreting statements from others, young children are able to use emotional prosody, or tone of voice, to determine a speaker's referential intent (Berman et al., 2010; Berman et al., 2013; San Juan et al., 2017). With respect to message production and repair, Wardlow and Heyman (2016) found that children (ages 5 to 7) who received nonverbal feedback after producing an ambiguous message (i.e., a confused facial expression) generated more effective messages across trials versus those who received no feedback. However, as the nonverbal feedback condition included two components: the listener made a confused facial expression *and* chose an incorrect choice (a salient cue for children based on Nilsen & Mangal, 2012), it is not possible to determine whether the facial expression specifically cued children to provide feedback. Aiming to examine the unique role of nonverbal feedback in 4- and 5-year-old children's communicative repair, Bacso and colleagues (2021) created a referential communication task wherein children attempted to tell a virtual child listener where to find a prize hidden in a box. When children provided a message that uniquely identified the prize location, the listener opened a box and made a happy facial expression. When children provided an ambiguous message, the listener opened a box and made a sad facial expression. After seeing the listener's expression, children were asked a series of questions (e.g., "How well do you think you described the box?") and then were asked if they would like to send another message to the listener. The researchers found that children were able to gauge their own communicative success based on the listener's facial expression and were more likely to attempt to repair their statements when the listener appeared sad. While this study provides insight into children's

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ability to use nonverbal cues to guide communication, by asking children to reflect on the messages and inquiring whether they would like to provide additional information, the exchange was interrupted. Thus, the extent to which children spontaneously attempt to repair their messages following nonverbal feedback (i.e., without probing questions) remains unknown.

In the present work we examined whether children use nonverbal cues that suggest confusion to repair their communicative behaviour. Preschool-age children can use nonverbal cues to detect uncertainty (Birch et al., 2010), but it remains to be determined whether they use this information to infer that a listener requires additional information and that they can then produce this information. In tandem, we explored whether nonverbal cues produced repairs that were as successful as verbal cues, as well as whether both cues together were particularly beneficial. The question as to the salience of verbal versus nonverbal streams is one that has been looked at in different aspects of communication. For instance, Morton and Trehub (2001) found that when verbal and nonverbal cues conflicted, children (but not adults) relied on the content of the speaker's message as opposed to the tone to determine the speaker's emotion, with this preference shifting through the school age-years. In the present work, we do not pit the different cues against one another, but rather determine whether there is added support by having both versus one type of information.

Cognitive Skills that Support Children's Repair Behaviour

There is a growing body of work showing that children's cognitive skills are associated with, and support, their communicative behaviour (see Matthews et al., 2018 for a review). In the current study, we explored whether children's executive functioning and emotional knowledge predicted their ability to identify miscommunication and to repair their messages.

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Executive functioning (EF) refers to a set of cognitive skills that facilitate goal-directed behaviour (Alvarez & Emory, 2006). Various components of children's EF skills relate to their ability to repair their messages in response to verbal feedback including cognitive flexibility (Bacso & Nilsen, 2017; Uzundag & Küntay, 2018) and working memory (Uzundag & Küntay, 2018). Inhibition has not been found to relate to children's communication repair (Bacso & Nilsen, 2017), however, inhibition is related to other aspects of children's communication skills (e.g., interpreting messages provided by a speaker; Nilsen & Graham, 2009; see Brown-Schmidt, 2009 for similar results in adults). EF has also been shown to relate to children's ability to use *nonverbal* feedback to guide their communicative repairs. For instance, in the aforementioned study by Wardlow and Heyman (2016), children's working memory skills were related to their performance in the nonverbal feedback condition (but not in the no feedback condition), suggesting that working memory facilitates children's ability to use the feedback to guide their production of subsequent messages. Further, in Bacso et al. (2021), children's EF skills (as measured by a latent EF variable) related to their ability to identify when miscommunication had occurred and their accuracy in gauging their own communicative success after receiving affective feedback, but not to their actual repair behaviour. Given the different methodologies, it is difficult to know whether EF plays a similar role in supporting message repairs following different types of feedback. Thus, in the present work, we examine associations between EF and children's communicative repairs following both verbal and nonverbal cues.

With respect to emotion knowledge, only a few existing studies have assessed children's emotion knowledge (EK), the ability to recognize and understand the affective states of others, in relation to their use of nonverbal cues within communicative contexts. This is surprising given the degree to which nonverbal cues have been found to support various communicative

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behaviours (Berman et al., 2010; Berman et al., 2013; San Juan et al., 2017; Wardlow & Heyman, 2016). This being said, a plethora of research has shown that children's EK is associated with their broader social skills (e.g., Bassett et al., 2012; Denham et al., 2003; Denham et al., 2012; Denham et al., 2015; Deneault & Ricard, 2013; Izard et al., 2001; Rhoades et al., 2009), though, the mechanisms through which EK supports children's social behaviour, including communicative aspects, are relatively unknown. Emerging work does suggest that EK may be associated with aspects of communication. For instance, Khu and colleagues (2017) found that 4-year-olds' EK was associated with their ability to understand a communicative partner's intentions from their affective prosody. In addition, Bacso and colleagues (2021) found that children with better EK were more likely to attempt to repair their messages when a listener appeared sad after receiving their initial message.

Together, this body of work suggests that children's EF and EK are associated with some aspects of detecting and repairing miscommunication. However, strong conclusions regarding how these skills may be more/less beneficial for using different types of feedback are limited by mixed findings and differing methodological designs across the studies.

Current Study

Addressing gaps in the literature, this study sought to determine the extent to which children could use verbal and nonverbal cues to detect and repair miscommunication, and the role that EF and EK play in supporting children's communicative skills. Knowing the sort of feedback that facilitates children's communicative repairs, as well as the cognitive skills that support such repair behaviour, has implications for our understanding of how children develop into competent communicators, as well as providing practical information regarding how caregivers can best support communicative development.

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Children (ages 4;0 – 5;11; years; months) completed a referential communication task where they attempted to tell a listener which box, out of an array of boxes, a prize was hidden in. Upon providing an ambiguous message (which, by design, occurred frequently), children received one of four types of feedback as a listener paused in making their choice: baseline (i.e., the listener appeared content), nonverbal cue only (i.e., the listener appeared confused), verbal cue only (i.e., the listener said “I don’t know which one you mean”) or verbal and nonverbal cues (i.e., the listener said “I don’t know which one you mean” *and* appeared confused). Feedback type was a within-subject variable such that participants were exposed to the different types of cues. By comparing each type of feedback to the baseline condition, we would be able to determine the extent to which children were able to use verbal and nonverbal feedback respectively to identify miscommunication and repair their messages. We also assessed the role of children’s EF and EK skills in their ability to repair their messages as well as improve their initial messages across trials.

We anticipated that children would infrequently repair their initially ambiguous messages within the baseline condition given the lack of direct feedback from a listener as to their confusion, though the pause alone may provide some cuing. Compared to this condition, we anticipated that children would be more likely to repair their messages when provided with nonverbal feedback and verbal feedback. We anticipated that children would be more likely to repair their messages in response to verbal feedback compared to nonverbal feedback or baseline. We were uncertain what would occur when both verbal and nonverbal feedback were provided. If we found that children’s repair behaviour in this condition was better than that of the verbal or nonverbal condition, it would suggest that both of these streams are providing unique information that children attend to such that performance is maximized. In contrast, if we found

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that, in this condition, children's performance was no different from either feedback type on its own, it would suggest that the information children received from each feedback type may be redundant. We also anticipated that children's EF and EK would be associated with both their tendency to repair their messages and the informativeness of their repairs (i.e., children with stronger skills in these areas would be more likely to attempt repairs and would provide more informative repairs), but that there may be an interaction between EK and the degree of nonverbal feedback, whereby children's EK would have a stronger association with repair behaviour within those conditions involving nonverbal cues. We speculated that children's cognitive skills, such as their EF and EK skills, could play a greater role in their performance when feedback from the listener is less detailed, and as such, children are less scaffolded by the listener in formulating a repair (as per Bacso & Nilsen, 2017). If this were the case, we would find an interaction between children's cognitive skills and the degree of verbal feedback provided, such that their cognitive skills play a greater role when verbal feedback is not provided.

Method

Participants

Participants were 70 children ($M_{age} = 5.04$ years; $SD = 0.60$ years; 33 females) ranging in age from 4;0 to 5;11 (years; months) recruited from a lab database in a mid-sized Canadian city, and online throughout North America. The sample consisted of 11 participants who were tested in-person ($M_{age} = 5.09$ years; $SD = 0.48$ years; 4 females) and 59 participants who were tested online ($M_{age} = 5.04$ years; $SD = 0.62$ years; 29 females) due to the COVID-19 pandemic⁶. Most

⁶ The testing environment (i.e., online versus in-person) was entered into the models as a control variable. In all cases there was no significant effect of the testing environment, so this was removed from models.

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children in the sample spoke English from birth (97%), and 23% of participants spoke another language other than English at home regularly. The original sample was 74 children, but data from four children was excluded (three children chose to discontinue their participation; one participant was not able to differentiate the stimuli due to color-blindness).

Our sample size was deemed to be sufficiently powered for estimating unbiased regression coefficients, standard errors, and variance components given that we had more than 50 observations of our level 2 factor (Maas & Hox, 2005; Paccagnella, 2011).

Procedure and Materials

Participants completed tasks in the order presented below.

Communication Task

Task Setup.

In-Person. Participants sat at a table across from a computer screen which showed the pre-recorded videos of another child of similar age (i.e., “Anne” who was the recipient of the children’s instructions, referred to below as the listener). The experimenter sat beside the participant and controlled which videos were played discretely using a Bluetooth keyboard.

Online. Participants participated from their home computers or iPads via Zoom videoconferencing software. The experimenter shared her screen with the participants and played videos of “Anne”.

Warm-up Procedures. Participants played a warm-up game that demonstrated that the listener could hear participants and respond to their messages but could not see them nor what was displayed on their screens. More specifically, the experimenter showed participants a picture of a banana, and instructed participants to help the listener to guess what the picture was of by giving her clues (e.g., instructing participants to tell the listener the colour). After the participant

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generated a clue (e.g., "it's yellow"), the experimenter played a video of the listener making a guess (i.e., "is it a sunflower?"). After the participant gave three clues to the listener, a video was shown where she correctly guessed that the object was a banana.

Practice Trials. Children completed three practice trials. During the first two practice trials, the experimenter showed children a card depicting four boxes with different pictures on each box (e.g., a flower, a sun, a cloud, and a tree) and told them they would be helping the listener find prizes hidden in boxes. The experimenter then showed children a video of boxes being placed in front of the listener. The camera panned across the boxes in front of the listener, showing that the boxes had the same pictures on them as those shown on the child's card, but in a different order. Participants were reminded that the listener could hear them but could not see them or their picture card. Next, the experimenter indicated which box the prize was hidden in (in-person: the experimenter placed a token on the target box on the card, and told the child, "it's in this one,"; online: there was a circle around the target box on the card displayed on the screen and the experimenter told the child "The prize is in the box that has the picture with the circle around it"). Participants then told the listener which box the prize was in. For the first two practice trials, each picture on the boxes was different, so the participant only needed to provide the object name to uniquely identify the target (e.g., "the one with the sun on it"). When the child provided a uniquely identifying message, they saw a video of the listener opening the target box and finding a candy inside. The third practice trial demonstrated to children that they were able to repair their initial messages. For this trial, the experimenter showed participants a card with seven boxes. There were two pictures of apples that differed by colour (green/red), which required that participants provide a descriptor (apple colour) in addition to the object name to unambiguously describe the target box. In almost all cases, participants failed to provide the

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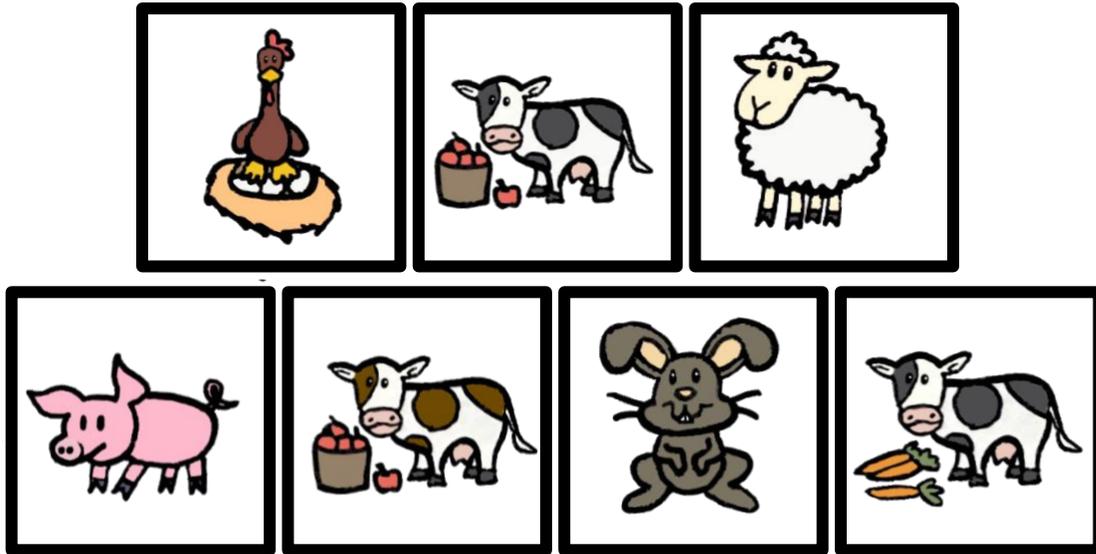
apple's color. When children provided this ambiguous description, a video was played of the listener looking back and forth across the boxes and the experimenter said, "Look at all the pictures and see if there's more information that could help Anne choose". In most cases, children then provided the apple's color, and a video was played of the listener picking up a box. However, in this video, the image on the box and the listener's reaction was not displayed. If children provided additional information, they continued to test trials. If children either initially provided a full description or failed to provide the apple's color after prompting, the same video of the listener opening the box was played and the experimenter told the child, "For the next ones, if you think Anne needs more information, look at all pictures and tell her more about the box so she can make the right choice".

Test Trials. On each test trial, participants were asked to describe the box a prize was hidden in for the listener (see Appendix C for a flow chart of test trial procedures). The procedures were the same as those described for the practice trials, where the experimenter showed children a card depicting the images on the listener's boxes and either placed a token beside the target box on the child's picture card (in-person) or the target box was circled on the child's picture card (online; see Figure 4). For test trials, participants were told that they would not be shown Anne's choice.

There were two different trial types, which varied in the number of descriptors required to uniquely identify the target box. On simple trials, similar to the first two practice trials, only the object name was required in order to uniquely identify the target box. Thus, there was a high likelihood that participants would provide an unambiguous response on their first attempt. That is, the target image was not similar to any of the distractor images (e.g., a pig, where the other

Figure 4

Example of Stimuli Used for the Communication Tasks.



Note. The child was told that the listener had boxes with the same cards printed on them. For this set of stimuli, the complex target was the black cow eating apples. The simple trial was the pig.

response options were cows, a rabbit, and a chicken). These trials were included to limit participants from adopting a response style where they described every detail of the target object whether it was needed or not. On complex trials, the main focus of analysis, the object name and two descriptors were required to uniquely identify the target box, thus, increasing the likelihood that participants would provide an ambiguous description on their first attempt. On these trials the image on the target box (e.g., a cow with black spots, eating apples) was similar to two distractor boxes, but varied on two dimensions, colour and associated object (e.g., a cow with brown spots, eating apples; a cow with black spots, eating carrots). As such, the object name and two descriptors were needed to uniquely identify the target (i.e., “the cow with black spots,

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eating apples"). Children completed a total of 15 trials (12 complex and 3 simple) in pseudorandom order.

After the participant provided their initial message, a video was shown of the listener's response. When children provided a uniquely identifying response, a video was played where the listener opened a box (without showing what picture was on it) and looked happy. From past work (Bacso et al., 2021), children recognize that this response means the message was successful. Following the video, the researcher continued to the next trial.

When children provided an ambiguous initial message, the listener's response was one of the four feedback types, programmed using Psychopy to present randomly. The conditions varied within subjects and consisted of a combination of verbal and nonverbal feedback:

- I. **Baseline:** Participants were shown a video of the listener pausing and appearing content, while saying nothing. In this condition, the listener pauses (i.e., does not immediately open a box), which could be indicative of listener uncertainty, but no additional nonverbal or verbal cues are present.
- II. **Nonverbal cues only:** Participants were shown a video of the listener pausing and then generating a confused facial expression, while saying nothing. The facial expression of the listener was one of puzzlement in a natural (i.e., not overly exaggerated) expression.
- III. **Verbal cues only:** Participants were shown a video of the listener pausing and appearing content, while saying, "I don't know which one you mean."
- IV. **Verbal and nonverbal cues:** Participants were shown a video of the listener pausing while looking confused and saying, "I don't know which one you mean."

After the video depicting the listener's response was played, children were given a 6-second pause and the experimenter indicated they could add more information whenever they liked until

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the listener made a choice.⁷ After this pause, a video was played of the listener opening up a box. If the child provided a response during their repair that uniquely identified the target box, a video was played of the listener opening up a box and appearing happy. If the child did not provide a full repair, a video was played of the listener opening a box with her facial expression not shown.

Coding of Communicative Behaviour. Children's initial messages and their attempts to repair their messages were coded. Responses were coded for object name (the name of the target object, e.g., "the cow"), number of descriptors (the number of informative descriptors provided during participants' initial messages; e.g., the cow with black spots, eating apples, would contain 2 descriptors), irrelevant descriptors (the number of descriptors provided during initial messages or repairs that do not help to disambiguate the target object from distractors; e.g., "the cow with a basket" when all cows are beside baskets), and new descriptors (informative descriptors provided during a repair that were not provided in the initial message). Only the number of informative initial descriptors and the number of new descriptors were used for analyses.

A secondary coder coded the behaviours of 15 randomly chosen participants (21% of the total sample) to ensure reliability. Interrater reliability for all responses was high (i.e., 98% agreement for the number of descriptors provided in initial statements and 100% agreement for the number of new descriptors following feedback).

Individual Difference Measures.

Executive Functioning (EF). EF was captured through participants' performance on tasks of working memory, cognitive flexibility, and inhibitory control.

⁷ This instruction was added because, during pilot testing, children indicated they were uncertain as to whether they were allowed to add any new information and/or just waited for the next trial.

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Inhibitory Control. We used the naming and inhibition tasks from the NEPSY-II (Korkman & Kirk, 2007) to assess children's inhibitory control. To limit test fatigue, only one trial of each trial type was administered (i.e., rather than the standard two). After a practice trial, children completed one naming trial and an inhibition trial. During these trials, children were shown 40 arrows pointing up and down. For naming trials, they were asked to say, "up", when an arrow was pointing up, and "down" when an arrow was pointing downwards. For inhibition trials they were asked to do the opposite and say "down" when an arrow was pointing up and say "up" when an arrow was pointing down, thereby inhibiting the prepotent response of accurately labelling the arrows. Stimuli (40 arrows) were presented on paper for in-person participants and on a computer screen for those who participated online. The residual change score of the number of errors children made on the inhibition trial compared to the number of errors they made on the naming trial was calculated. This resulted in a score that reflected participants' inhibition skills, controlling for their naming skills. The change score was reflected (multiplied by -1) such that higher scores reflected better performance to be consistent with other measures of EF.

Cognitive Flexibility. We used the Object Classification Task for Children (OCTC; Smidts et al., 2004) to assess children's cognitive flexibility. During this task, children sort toys by color, function, and size. The toys consisted of a small yellow plane, small red plane, large red plane, large red car, large yellow car, and small yellow car. Actual objects were used for in-person participants whereas images on a computer screen (which included two boxes to 'put objects in') were used for online participants who pointed instead of moving objects. Participants were first asked to sort the toys into two groups in as many ways as they could. Online participants instead told the experimenter what groups they would make. Children were awarded 3 points for each correct sort, and an additional point for labelling the sorting criteria. If they

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were unable to sort the toys based on color, function, and size, the experimenter created the groups that were missed, and asked the child what was the same about the toys in the groupings she made. Children received 2 points for each correctly labeled sorting. If they were unable to label all possible sortings, the experimenter asked them to create groups based on the criteria they had missed. Online, children were asked to point on the screen based on whichever criteria were missed (e.g., Can you point to all the red ones that can go in the red box and all the yellow ones that can go in the yellow box?). Children received 1 point for each correct grouping. Total scores could range from 0 to 12.

Working Memory. We assessed children's working memory using the Digit Span subtest from the Wechsler Intelligence Scale for Children—Fourth Edition (Wechsler, 2003). First, children completed the digit span forwards test, during which they repeated a series of digits read aloud by the experimenter. Following this, they completed the digit span backwards subtest, during which they repeated a series of digits read aloud by the experimenter in a backwards order. Children received a total score combining forwards and backwards tasks, out of a maximum possible score of 32.

Emotion knowledge (EK). We captured two aspects of children's EK by combining the scores from the emotion labelling and emotion understanding tasks to create an EK composite.

Emotion Labelling. The Assessment of Children's Emotion Skills (ACES; Schultz et al., 2004) assessed children's emotion labelling skills. The experimenter showed children a series of 16 pictures of children displaying various emotions and asked them what each child felt from the options of happy, sad, mad, or scared.

Emotion Understanding. The Emotion Recognition Questionnaire (ERQ; Ribordy et al., 1988) assessed children's emotion understanding. The experimenter read children 12 vignettes

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(from the original 16) that depicted a series of situations and asked children how the main character in each vignette would feel out of three options.

Expressive vocabulary. The Picture Naming task from the Wechsler Preschool and Primary Scale of Intelligence–Third Edition (Wechsler, 2002) was used to assess Expressive vocabulary, which was used as a control measure due to its associations with both referential communication and EF (Bacso & Nilsen, 2017; Nilsen & Graham, 2009). For this task, children named a series of pictures that were presented to them. Children's raw scores (/24) were used for analyses.

Results

Preliminary Analyses

The standardized residuals of regression analyses for continuous dependent variables showed normal distributions. The independent variables also showed acceptable ranges (OCTC min = 3, max = 12; Digit span total score min = 2, max = 16; Inhibition total errors min = 0, max = 21; ACES min = 4, max = 15; ERQ min = 5, max = 12).

Only data from complex trials was used for analyses because these were the trials during which the informativeness of children's messages could be evaluated. Correlations between outcome variables can be seen in Table 9 and Table 10.

Model of Executive Functioning

With the goal of reducing task-specific variance (Kaushanskaya et al., 2017), we created a measurement model of an EF latent variable using children's digit span, OCTC scores, and reflected residual change scores on the inhibition task (see Table 11) using the Lavaan package in R using maximum likelihood estimation (R Core Team, 2013). However, we found that the factor loadings of each EF task onto the EF factor were not statistically significant, which

suggests that the EF tasks did not converge onto one factor in this sample. As such, we decided to use children's scores on each EF task for further analyses rather than using the EF latent variable.

Methods for Analyses

To examine the relative effects of each feedback condition on children's communicative performance, and to assess the role of EF and EK on communicative performance, we created several mixed models. We used multilevel models, given the hierarchical nature of the data. The within-subjects factor of trial would be a level 1 factor, whereas participants would be the level 2 factor. Multilevel modelling controls for idiosyncratic differences across trials and across participants by allowing for residual components at each level of this hierarchy. Multilevel models are also better able to handle missing data, which occurred in this study since participants did not always repair their messages on each trial (i.e., sometimes children provided a uniquely identifying message during their initial attempt and, thus, repairs were not needed). We used the *lmer()* function and *glm()* function of the lme4 package (Bates et al., 2013) in R to create models. For numerical outcome variables (e.g., number of new descriptors), we used linear models (LMs), whereas for binary outcome variables (e.g., decision to repair = yes or no) we used generalized linear models (GLMs), which are equipped to handle binary outcome data.

Base models included the random intercepts for participants. For each set of analyses, the random slopes model (with random slopes for participants across trials) was compared to the random intercepts model. In most cases there was no significant difference in model fit, so the random intercepts model was used. Instances where this was not the case are noted. Models that examined children's repairs followed a 2x2 factorial design (i.e., verbal feedback x nonverbal

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Table 9

Means, Standard Deviations, and Correlations with Confidence Intervals with the Number of Descriptors Provided During Children’s Initial Messages.

Variable	<i>M</i>	<i>SD</i>	1	2	3	4	5	6
1. Age (months)	60.53	7.16						
2. EK	0.05	0.99	.28* [.04, .48]					
3. Working memory	8.54	3.13	.66** [.50, .78]	.44** [.22, .61]				
4. Inhibition	0.07	4.03	.05 [-.22, .32]	.19 [-.09, .44]	.05 [-.23, .31]			
5. Cognitive flexibility	8.37	2.39	.31* [.07, .51]	.25* [.01, .46]	.19 [-.05, .41]	.32* [.06, .54]		
6. Expressive vocabulary	18.63	2.54	.34** [.11, .54]	.38** [.15, .56]	.40** [.18, .59]	.21 [-.07, .45]	.21 [-.04, .43]	
7. Initial message: descriptors ¹	1.10	0.83	.28** [.12, .44]	.29** [.13, .46]	.30** [.14, .46]	.05 [-.15, .24]	.29** [.12, .45]	.36** [.21, .51]

Note. *M* and *SD* are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. The confidence interval is a plausible range of population correlations that could have caused the sample correlation. * indicates $p < .05$. ** indicates $p < .01$. Data is from complex trials only and includes trials where a uniquely identifying message was provided and trials where an ambiguous message was provided.

¹ Correlations between number of descriptors and other variables are multilevel correlations.

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Table 10

Means, Standard Deviations, and Odds Ratios or Correlations Across Feedback Types with Confidence Intervals with Children’s Likelihood of Attempting a Repair and the Number of New Descriptors Added During Repairs.

Variable	<i>M</i>	<i>SD</i>	Age (months)	Expressive vocab.	Working memory	Inhibition	Cognitive flexibility	EK
Likelihood of attempting a repair ¹	0.66	0.47	1.08 [0.97, 1.20]	1.80 [0.87, 3.74]	2.48* [1.16, 5.28]	1.10 [0.51, 2.34]	1.47 [0.71, 3.04]	1.01 [0.47, 2.18]
Repairs: new descriptors ²	0.69	0.61	.24** [.07, .41]	.24** [.08, .40]	.25** [.09, .41]	.00 [-.18, .19]	.07 [-.09, .24]	.23* [.05, .40]

Note. Note that only data where children provided an initially ambiguous message are included here. *M* and *SD* are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval. Correlations between age, expressive vocabulary, EK and EF components are presented in Table 1.

* indicates $p < .05$. ** indicates $p < .01$

¹ Odds ratios are reported rather than correlation coefficients given that likelihood of attempting a repair was a binary outcome variable.

² Multilevel correlations are reported between children’s likelihood of attempting a repair and other variables.

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Table 11

Factor Loadings, Standard Error, Z-Values, and p-Values for Indicators of the Executive Functioning Latent Variable.

Indicator	β	<i>B</i>	<i>SE</i>	<i>Z</i>	<i>p-value</i>
Digit Span	0.18	0.56	0.79	0.70	.48
Inhibition	0.31	1.26	1.69	0.74	.46
OCTC	1.05	2.49	3.13	0.79	.43

feedback). Feedback conditions were dummy coded based on the presence or absence of each type of cue. Verbal feedback consisted of the verbal cues only and verbal and nonverbal cues conditions. Nonverbal feedback included the nonverbal cues only and verbal and nonverbal cues conditions. The interaction term between nonverbal feedback and verbal feedback reflected the verbal and nonverbal cues condition, which included both types of feedback. The reference category was set to be the baseline condition. As such, analyses compared each condition to the baseline condition.

To examine the effect of EF components and EK on children’s communicative performance, each variable of interest was added to the model separately and model fit was compared to the base model. As we were interested in the overall associations between these skills and repair behaviour, EF components were not analyzed together in models with EK. The models (without covariates) were then compared to models with covariates (age, gender, online vs. in-person participation, expressive vocabulary) to determine if covariates should be controlled for in the models. In most cases, including covariates did not result in a significant difference in model fit ($p > .05$), so these variables were not included in final models used for interpretation. We note where a covariate was included. We also compared models including the fixed effect of trial with models not including this effect to assess whether children’s responses

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varied across trials. In most cases, there was no significant effect of trial, so this was trimmed from the models.

Below, results are presented for each dependent variable, namely, number of descriptors in initial messages, repair attempts, and repair informativeness (i.e., number of new descriptors). The main research questions are addressed together in models of the latter two dependent measures, namely, which cues are most effective for indicating to children that they need to repair their description (verbal, nonverbal, or both) and to what degree do EF and EK relate to their ability to realize the need for a repair and their ability to implement successful repair behaviour. However, to provide context for these questions, children's initial messages (i.e., prior to listener feedback) are presented first.

Initial Messages: Number of Descriptors

Children provided ambiguous responses on their first attempt on 59% of complex trials, suggesting that our design was effective in creating a scenario where a message repair was needed. To further explore children's initial descriptions, we fit a mixed-effects regression model with a dependent variable of the number of descriptors provided during initial messages. A one-way ANOVA comparing the random intercept and random slopes models revealed that the random slopes model fit significantly better, $\chi^2(2, n = 832) = 47.26, p < .001$, so the random slopes model was used for analyses involving children's initial messages. We also added the fixed effect of trial to the model, which resulted in significantly better model fit, $\chi^2(1, n = 832) = 19.37, p < .001$. We then added the EF variables or EK variables to the model separately and compared model fit, with the results described below.

Working Memory

When children's scores on the digit span task were added to the base model, the model fit significantly improved, $\chi^2(1, n = 799) = 11.59, p < .001$. The only covariate that resulted in a better model fit was expressive vocabulary, $\chi^2(1, n = 799) = 11.65, p < .001$. The best-fitting model (Table 12, Model 1a) indicated that there were significant main effects of trial, working memory, and expressive vocabulary.

Inhibition

When children's scores on the inhibition task were added to the base model, the model fit did not improve, $\chi^2(1, n = 634) = 0.21, p = .65$. As such, the model including inhibition was not explored further.

Cognitive Flexibility

When children's scores on the object classification task were added to the base model, the model fit significantly improved, $\chi^2(1, n = 799) = 10.51, p = .001$. Adding expressive vocabulary also significantly improved model fit, $\chi^2(1, n = 799) = 16.25, p < .001$. The best-fitting model (Table 12, Model 1b) indicated that there were significant main effects of cognitive flexibility, trial, and expressive vocabulary.

All Executive Functioning Components

The models above indicated that children with better working memory and cognitive flexibility produced more descriptions in their initial statements. To probe results further, namely, to determine the *unique* contributions of each component of executive functioning, we added all three components to one model predicting the quality of children's initial messages. When all three components of EF were added to the base model together, the model fit significantly improved, $\chi^2(3, n = 634) = 12.14, p = .006$. Adding expressive vocabulary to the

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model also significantly improved model fit, $\chi^2(1, n = 634) = 9.62, p = .002$. The best-fitting model (Table 12, model 1c) indicated that there were significant main effects of trial and expressive vocabulary. There were marginally significant effects of working memory and cognitive flexibility, suggesting that while these skills are important in supporting children's production (as per models above and their combined effect), the unique contribution of each is marginal.

Emotion Knowledge

Assessing EK, when this composite variable was added to the base model the model fit significantly improved, $\chi^2(1, n = 799) = 11.61, p < .001$, as was the case when expressive vocabulary was added, $\chi^2(1, n = 799) = 12.14, p < .001$. The best-fitting model (Table 12, Model 2) revealed a significant main effect of EK, such that children with stronger EK provided more effective initial messages, even when controlling for expressive vocabulary. As well, there was a significant effect of trial, with participants providing more descriptors on each subsequent trial.

Initial Messages: Summary

Together results indicate that children with better working memory, cognitive flexibility, and emotional knowledge provided more descriptive initial messages, even when controlling for vocabulary abilities. However, in general, in this referential context, children frequently failed to provide sufficient information for the listener to identify the target. This was an anticipated feature of our task which allowed us to look at what children do when they are provided with different types of feedback indicating that their message is in need of repair.

Table 12

Details of the Best-Fitting Mixed-Effects Models for Descriptors Provided During Initial

Messages.

Model	Fixed Effects			
Model 1a Executive Functioning Working Memory	Working memory + Trial + Expressive vocabulary Predictors:			
	β	95% CI	p	
	Working Memory	0.17	[0.01, 0.34]	.04
	Trial	0.16	[0.09, 0.22]	<.001
	Expressive Vocab.	0.29	[0.12, 0.45]	<.001
Model 1b Executive Functioning Cognitive Flexibility	Cognitive flexibility + Trial + Expressive vocabulary Predictors:			
	β	95% CI	p	
	Cognitive flexibility	0.22	[0.07, 0.36]	.005
	Trial	0.16	[0.09, 0.22]	<.001
	Expressive Vocab.	0.31	[0.17, 0.46]	<.001
Model 1c Executive Functioning All Components	Working memory + Inhibition + Cognitive flexibility + Trial + Expressive vocabulary Predictors:			
	β	95% CI	p	
	Working memory	0.17	[-0.01, 0.34]	.07
	Inhibition	-0.07	[-0.24, 0.11]	.44
	Cognitive flexibility	0.16	[-0.01, 0.33]	.08
	Trial	0.18	[0.10, 0.26]	<.001
	Expressive Vocab.	0.28	[0.10, 0.45]	.003
Model 2 Emotion Knowledge	EK + Trial + Expressive vocabulary Predictors:			
	β	95% CI	p	
	EK	0.18	[0.02, 0.34]	.03
	Trial	0.16	[0.09, 0.22]	<.001
	Expressive Vocab.	0.29	[0.13, 0.44]	<.001

Repair Behaviour: Likelihood of Attempting a Repair

Looking only at those trials where children failed to provide a uniquely identifying message on their first attempt, children chose to attempt a repair on 66% of trials. See Figure 5 for children's likelihood of repairing their messages across the different feedback conditions. To determine whether children responded differently to the feedback types, we fit a mixed effects model that compared the relative effects of verbal and nonverbal feedback on children's likelihood of attempting to repair their messages for those trials where children failed to uniquely identify a target on their first attempt. The dependent variable was whether children attempted to repair their message (0 = no, 1 = yes). A one-way ANOVA comparing the random intercept and random slopes models found no significant difference in model fit, $\chi^2(2, n = 503) = 0.02, p = .99$, so the random intercepts model was used for analyses involving children's tendency to repair their messages.

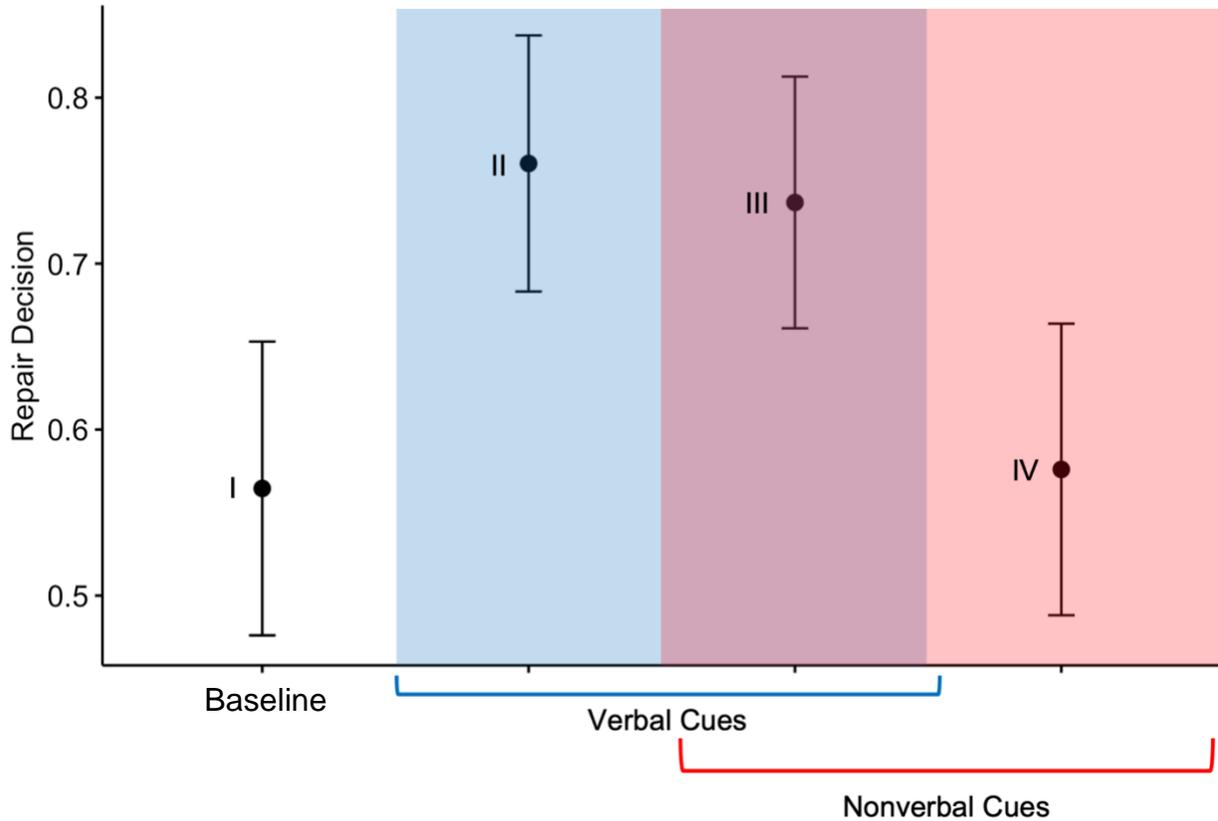
We found that children were significantly more likely to repair their messages when provided with verbal feedback (see Table 13, Model 1) compared to when they received no feedback. There was no significant effect of nonverbal feedback on children's tendency to repair their messages. The interaction between verbal and nonverbal feedback was non-significant, $\chi^2(2, n = 503) = 0.51, p = .47$, suggesting there was no advantage to receiving nonverbal information when verbal cues were present. We also tested the effect of adding the fixed effect of trial to the model and found no significant difference in model fit, $\chi^2(2, n = 503) = 0.37, p = .54$.

Working Memory

Adding working memory to the base model significantly improved model fit, $\chi^2(1, n = 484) = 6.02, p = .01$, indicating there was a significant main effect of working memory in

Figure 5

Mean Likelihood of Repair Attempt in Each Feedback Condition.



- I. **Baseline:** Participants were shown a video of the listener pausing and appearing content, while saying nothing. (*attempted repair on 56% of trials*)
- II. **Verbal cues only:** Participants were shown a video of the listener pausing and appearing content, while saying, “I don’t know which one you mean.” (*attempted repair on 76% of trials*)
- III. **Verbal and nonverbal cues:** Participants were shown a video of the listener pausing while looking confused and saying, “I don’t know which one you mean.” (*attempted repair on 74% of trials*)
- IV. **Nonverbal cues only:** Participants were shown a video of the listener pausing with a confused facial expression, while saying nothing. (*attempted repair on 58% of trials*)

Note. Error bars represent 95% confidence intervals.

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predicting children’s tendency to repair their messages (see Table 13, Model 2). Model fit was not improved through adding covariates or interactions between working memory and feedback type.

Inhibition

Adding inhibition to the base model did not significantly improve model fit, $\chi^2(1, n = 362) = 0.02, p = .89$, nor was the model improved when interactions between inhibition and feedback type were added.

Cognitive Flexibility

Adding cognitive flexibility to the base model did not significantly improve model fit, $\chi^2(1, n = 484) = 0.95, p = .33$. In addition, there were no interactions between cognitive flexibility and feedback type.

Table 13

Details of the Best-Fitting Mixed-Effects Model for Children’s Likelihood of Attempting a Repair.

Model	Fixed Effects			
Model 1 Base Model	Verbal + Nonverbal			
	Predictors:			
		β	95% CI	p
	Verbal	1.77	[1.10, 2.44]	<.001
	Nonverbal	-0.08	[-0.69, 0.52]	.79
Model 2 Executive Functioning Working Memory	Verbal + Nonverbal + Working memory			
	Predictors:			
		β	95% CI	p
	Verbal	1.73	[1.05, 2.41]	<.001
Nonverbal	-0.14	[-0.77, 0.49]	.67	
Working memory	2.23	[0.37, 4.10]	.02	

All Executive Functioning Components

When all three components of executive functioning were added to the base model together, the model fit did not significantly improve, $\chi^2(3, n = 362) = 1.61, p = .66$, suggesting that, when added together, the EF components do not relate to children's likelihood of repairing their messages.

Emotion Knowledge

Adding EK to the base model also did not significantly improve model fit, $\chi^2(1, n = 484) = 0.0006, p = .98$. There were no interactions between emotion knowledge and feedback type. As a result, this model was not explored further.

Likelihood of Repair Attempt: Summary

In sum, children with stronger working memory were more likely to attempt to repair their messages than children with weaker working memory. Similar associations were not found for cognitive flexibility or inhibition, nor did the EF variables together predict children's likelihood of repairing their messages. However, it should be noted that there were fewer observations in the combined model due to missing participant data for the inhibition task (i.e., $n = 362$ when all components of EF were included in a model together, but $n = 484$ when digit span was in its own model).

Repair Behaviour: Number of New Descriptors in Repairs

For those trials where children attempted a repair, they provided one or more *new* informative descriptors on 61% of attempts. They were able to uniquely identify the target after repairing their messages on 31% of trials. They added irrelevant descriptors on 33% of trials and repeated their initially ambiguous message on 19% of trials.

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To examine how successful children were at repairing messages following each feedback type, we fit a mixed effects model including the number of new informative descriptors provided during repairs as the dependent variable. Comparison of a random slopes and random intercepts model revealed no significant differences in model fit, $\chi^2(2, n = 333) = 2.26, p = .32$, so a random intercepts model was used.

Within the base model, we found that there was no significant impact of verbal feedback on children's repair behaviour compared to when children received no feedback, however, the effect of nonverbal feedback was marginally significant, suggesting that children were marginally likely to provide less new descriptors after seeing the listener appear confused. This was the model used to examine the individual differences (presented below) as there was no significant interaction between verbal and nonverbal feedback, $\chi^2(1, n = 333) = 0.21, p = .65$, and adding the fixed effect of trial to the model did not result in improved model fit, $\chi^2(1, n = 333) = 1.82, p = .18$.

Working Memory

Adding working memory to the base model resulted in significantly improved model fit, $\chi^2(1, n = 329) = 8.78, p = .003$, suggesting a significant main effect of working memory (see Table 14, Model 1a). The model fit was not improved through adding covariates or interactions between working memory and feedback type.

Inhibition

Adding inhibition to the base model did not result in a significant change in model fit, $\chi^2(1, n = 250) = 0.08, p = .77$, nor was the model fit improved by adding interactions between inhibition and feedback type.

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Cognitive Flexibility

Adding cognitive flexibility to the base model did not result in a significant change in model fit, $\chi^2(1, n = 329) = 0.95, p = .33$. Also, there were no interactions between cognitive flexibility and feedback type. As a result, this model was not explored further.

All Executive Functioning Components

When all three components of executive functioning were added to the base model together, the model fit significantly improved in relation to the base model, $\chi^2(3, n = 250) = 8.21, p = .04$. With respect to specific components, the model revealed a significant main effect of working memory (see Table 14, Model 1b).

Emotion Knowledge

EK was added to the base model to examine its associations with children's repair informativeness, resulting in significantly improved model fit, $\chi^2(1, n = 329) = 6.65, p = .01$ (see Table 14, Model 2). The model indicated that children with stronger EK provided more effective repairs than those with weaker EK skills. The model fit was not improved when trial, any covariates, and interactions between EK and feedback types were added to the model.

Number of New Descriptors in Repairs: Summary

We found that children's working memory skills, but not inhibitory control or cognitive flexibility, significantly predicted the quality of their repair statements. When all three components of EF were included in the model together, working memory remained a significant predictor of children's quality of their repair statements. Emotion knowledge also significantly predicted the quality of children's repair statements, such that children with higher emotion knowledge provided more descriptors in their repairs.

Table 14

Details of the Best-Fitting Mixed-Effects Models for the Number of New Descriptors Added to Children’s Messages During Repairs.

Model	Fixed Effects			
Model 1a	Verbal + Nonverbal + Working memory			
Executive Functioning	Predictors:	β	95% CI	<i>p</i>
Working Memory	Verbal	0.05	[-0.05, 0.14]	.33
	Nonverbal	-0.08	[-0.18, 0.007]	.07
	Working memory	0.25	[0.09, 0.41]	.004
Model 1b	Verbal + Nonverbal + Working memory + Inhibition + Cognitive flexibility			
Executive Functioning	Predictors:	β	95% CI	<i>p</i>
All Components	Verbal	0.03	[-0.08, 0.14]	.57
	Nonverbal	-0.10	[-0.21, 0.01]	.09
	Working memory	0.25	[0.07, 0.43]	.009
	Inhibition	-0.02	[-0.20, 0.16]	.84
	Cognitive flexibility	0.05	[-0.13, 0.23]	.58
Model 2	Verbal + Nonverbal + EK			
Emotion Knowledge	Predictors:	β	95% CI	<i>p</i>
	Verbal	0.04	[-0.05, 0.14]	.37
	Nonverbal	-0.09	[-0.18, 0.007]	.07
	EK	0.23	[0.06, 0.41]	.01

Discussion

Children’s ability to successfully convey information is a critical aspect of their communicative development, with the act of repairing miscommunication being essential given the challenges children demonstrate in providing sufficient referential descriptions. However, the differing methodology across studies limits our ability to understand how children make use of different types of feedback from a conversational partner to generate repairs and the cognitive skills that enable them to do so. We examined children’s ability to recognize when additional information is needed and to successfully repair a previously ambiguous message, based on

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verbal and/or nonverbal feedback from a listener. As well, we assessed the role of children's EF and EK in their ability to repair their messages following different feedback types.

Children's Repair Behaviour Following Verbal and Nonverbal Cues

Our task, as designed, tended to elicit ambiguous descriptions from children. Thus, we were able to examine both the extent to which children chose to repair their initially ambiguous messages, as well the informativeness of repairs, in response to verbal and nonverbal feedback from a listener indicating confusion.

Likelihood of Attempting a Repair

Consistent with our hypotheses, children tended to attempt to repair their messages more frequently when receiving verbal feedback (i.e., "I don't know which one you mean") compared to the baseline condition (i.e., listener looking content). Contrary to our predictions, there was no benefit to receiving nonverbal feedback (i.e., a confused facial expression) compared to the baseline condition. Lastly, there was no added benefit to receiving both verbal and nonverbal feedback simultaneously, compared to just receiving verbal feedback alone. These findings suggest that, in this context, the nonverbal facial cues provided by the listener are not providing additional cues that prompt children to repair their statements beyond the baseline condition – but verbal cues do. It is unlikely that this finding was a result of children not understanding the nonverbal cue given that work by Birch and colleagues (2010) found that children use this cue to selectively learn from others. While it may be tempting to conclude that children do not use nonverbal information in the context of repairing statements, we do not feel this general conclusion is warranted. Rather, our interpretation is that in the present study, the verbal cues might be so salient that the nonverbal cues are ignored or discounted by children, in essence, children "waiting" for the verbal cues rather than taking the nonverbal cue as an indication to

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repair. It may be the case that if children never received verbal feedback, they would have shown a greater number of repair attempts following nonverbal feedback. Indeed, Bacso and colleagues (2021) utilized a design where no verbal cues were provided and found that children were able to use a listener's affective state (happy/sad) to guide their decision about whether to attempt a repair or not. Moreover, it is important to consider the nature of the baseline condition, which was used as the comparison point: while not providing facial nonverbal information, it did provide children with information about the needs of the listener, namely, that the pause indicated they were not able to make a decision. Children have been shown in previous work to respond to various types of nonverbal feedback such as pointing and facial expressions (see Ateş & Küntay, 2015 for a review). Indeed, work from the dysfluency literature suggests that preschool-age children are sensitive to pauses (albeit filled ones, e.g., saying "um") and interpret them as indicating uncertainty (White et al., 2019). Past work also suggests that older children (ages 7 to 8) are sensitive to other cues of uncertainty, such as pauses (as well as intonation and eyebrow movements), although they are less sensitive to these cues than adults (Krahmer & Swertz, 2005). Thus, it is likely that within the current study children interpreted the pause as confusion and as a result, further facial cues indicating confusion did not add benefit. In contrast, and importantly, the verbal information did provide an additional signal that more information was required.

Demonstrating the value of verbal feedback for children's decision to repair adds to the broader literature that shows that young children are able to detect and repair ambiguity in their messages after receiving a variety of types of feedback from a listener (Bacso & Nilsen, 2017; Coon et al., 1982; Deutsch & Pechmann, 1982; Nilsen & Mangal, 2013; Uzundag & Küntay, 2018). Our findings also demonstrate that children respond differently to differing types of

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feedback, in this case with verbal information providing a more salient cue than nonverbal.

However, we found that children were able to repair their messages after receiving minimal cues from the listener (i.e., the baseline condition). Thus, our work indicates that while children repaired more readily following verbal feedback from a listener, they showed sensitivity to a subtle cue (pause) indicating that their messages have not been effectively understood.

Informativeness of Repairs

In addition to knowing when to provide additional information, successful repairs require that more information is added. Indeed, early work suggests that while children at the age of 2 understood that miscommunication had occurred, they adopted inadequate strategies for repairing the communication (e.g., continued pointing rather than adding differentiating verbal information; O'Neill & Topolovec, 2001). In the present study, we found that the type of feedback provided by the listener did not have a significant influence on the informativeness of their repairs. That is, while the type of feedback influenced children's decision to provide additional information, it did not affect the success of these attempts. While this finding differs from our predictions, on reflection, it is not surprising given that neither the verbal nor the nonverbal cue provided *specific* information about what was missing/needed. That is, past research has found that more detailed listener feedback results in children providing more information during repairs – for instance, detailed verbal cues such as, “I picked the wrong one. There are two boys in red shirts, and I don't know which one you mean” yielded more informative repairs versus a vague cue, “I picked the wrong one. I don't know which one you mean”. In light of this past work, the present findings make sense – that is, while verbal cues regarding confusion prompt children to repair more than nonverbal cues, because they do not provide specific information, the actual success of attempts is equivalent across cue types.

Learning over Trials

Although children tended to provide ambiguous messages initially, they generated more descriptors as the trials progressed, suggesting that they learned from the experience and feedback (consistent with past work: Bacso & Nilsen, 2017; Bacso et al., 2021; Matthews et al., 2007; Matthews et al., 2012). Thus, even though none of the feedback types included specific information about what was missing, children learned from their unsuccessful communicative experiences and indication from the listener that she was confused. Rabagliati and Robertson (2017) have asserted that for children to develop their skills as speakers, that is, learning to provide more effective messages over time, they may require an “error signal” to detect whether or not they have avoided ambiguity. Our findings suggest that verbal feedback operates as a stronger error signal relative to nonverbal feedback. However, as children were choosing to repair on approximately half of trials in the baseline condition, the pause also seems to also be providing a signal. To probe this finding further, a future study could include trials where a listener chooses an object promptly and compare other feedback types, including a paused trial.

Role of Executive Functioning and Emotion Knowledge

Our design allowed us to examine whether children's socio-cognitive skills were associated with their initial statements and repair behaviour, and importantly, whether the associations with repair behaviour might differ according to the type of feedback a listener provided.

Children's Initial Messages

Children's working memory and cognitive flexibility were associated with the quality of their initial messages, even when controlling for expressive vocabulary (which was also related to the informativeness of their messages). The association with these EF components found here is

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consistent with previous work showing that EF is associated with the quality of children's initial messages (Uzundag & Küntay, 2018; Wardlow & Heyman, 2016). For instance, Bacso and Nilsen (2017) found that children's cognitive flexibility and working memory were associated with the quality of their initial messages. Moreover, adding novel information about the skills that support children's effective production of messages, EK was associated with the informativeness of children's initial messages.

Communication Repair

Building on past work (Bacso & Nilsen, 2017; Uzundag & Küntay, 2018), children with better executive functioning (in particular working memory), demonstrated better repair behaviour. That is, those children who demonstrated greater working memory capacity were found to attempt their repairs more often and be more successful in doing so in that a greater amount of additional information was provided. Cognitive flexibility was not found to be associated with children's repair behaviour, which contrasts Uzundag and Küntay (2018) and Bacso and Nilsen (2017). Though, in these past studies, the listener provided specific verbal feedback, which highlighted different properties of the objects (e.g., colour, associated objects). In these contexts, children may have been prompted to view stimuli in more flexible ways, thereby relying on their cognitive flexibility skills (Gillis & Nilsen, 2014). We did not find that there were significant interactions between EF components and feedback type in predicting children's tendency to repair their message or the informativeness of their repairs. As such, contrary to our hypotheses, the cognitive demands of repair appear to be similar across the different types of feedback provided.

With respect to children's EK, we found that there was not a significant association between EK and repair attempts following the generation of an ambiguous message. However,

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consistent with our hypotheses, EK was related to the informativeness of children's repairs. This finding suggests that children with stronger EK may have a greater understanding of what to do after the listener's feedback indicates that their initial message was ambiguous. This association was across feedback types. That is, there was not a stronger association following one type of feedback versus another, for instance the presence or absence of nonverbal cues. However, as mentioned earlier, the baseline condition (with the pause) also may have provided some information as to the listener's informational needs. This work is somewhat consistent with past work which finds that children with stronger EK are more likely to repair their messages after receiving nonverbal feedback (Bacso et al., 2021). Thus, there is converging evidence for the importance that EK plays in children's communication repair. It may be the case that children with stronger EK are more likely to be attuned to the needs of the listener. Indeed, past evidence demonstrates that children with stronger EK are more socially competent, as rated by peers (Denham et al., 1990; Fabes et al., 2001; Garner & Estep, 2001) and teachers (Bassett et al., 2012; Denham et al., 2003; Denham et al., 2012; Denham et al., 2015; Deneault & Ricard, 2013; Izard et al., 2001; Rhoades et al., 2009). Moreover, children with stronger EK respond more prosocially to the emotional displays of others (Denham 1986; Denham & Couchoud, 1991). The present study adds to this literature demonstrating that children with better EK are better able to support the informational needs of their conversational partner following initial miscommunication. It will be important for future work to further probe the nature of the relations between EK and communication to more fully understand when children draw on this skill and whether there are underlying processes that account for this association.

Implications

The findings from this work have both research and practical implications. With respect to research, findings highlight the degree to which different aspects of communicative behaviour need to be identified within tasks – as the saliency of cues and associations with socio-cognitive skills may differ across the different elements. Findings also have practical implications for the ways in which parents and caregivers can support their children in becoming more effective communicators. Our findings suggest that providing children with verbal feedback indicating they have been misunderstood is more effective in prompting them to repair their unclear messages compared to nonverbal feedback. Related to this, detailed feedback indicating what specifically was lacking in the original message is even more effective for successful repairs (Bacso & Nilsen, 2017).

Our findings suggest that EF and EK play an important role in children's production and repair of referential statements. Working memory and cognitive flexibility showed associations with the quality of children's initial messages, and working memory showed associations with children's repair behaviour. EK also showed associations with the quality of children's initial messages and with the informativeness of children's repairs. Such findings suggest that interventions to improve children's EF or EK may lead to improvements in their communication skills (although existing EF training programs have shown limited effectiveness in generalizing outside of specific tasks; see Sala & Gobet, 2017 and Aksayli et al., 2019 for meta-analyses, and Gunzenhauser & Nückles, 2021 for a review; EK programs: Izard et al., 2008; Ornaghi et al., 2017; Richard et al., 2020; Whitcomb & Merrell, 2012).

Limitations and Future Directions

While providing insight into children's use of feedback for repairing miscommunication, there are considerations to note. In particular, it is useful to consider our approach to EF, given that EF is treated in different ways across the past literature (e.g., components assessed, tasks used, unitary versus multiple constructs), and results may differ based on whether a latent variable is used or individual components of EF are assessed (see Camerota et al., 2020 for a discussion on the importance of EF measurement). In the present study, a latent variable was planned, but not used because the factors did not converge. Certainly, using a latent variable would have reduced task-specific variance and measurement error (Kaushanskaya et al., 2017; Tabachnick & Fidell, 2013). Such an approach is also consistent with theoretical models of EF, suggesting that EF in preschool-aged children is a unitary construct (Brocki & Bohlin, 2004; Hughes et al., 2010; Nilsen et al., 2017; Wiebe et al., 2011; see Karr et al., 2018 for a review), although other work suggests it consists of two factors (Miller et al., 2012; Müller & Kerns, 2015). However, in measuring EF this way, the specific role of EF components cannot be obtained. In our work, we were able to speak to the associations with each EF component, as well as articulate how unique that association was through a model that included all EF components. In future work, it would be advantageous to include multiple tasks for each EF component in order to reduce task-specific variance and allow for the possibility of computing latent variables for each component of EF, thereby allowing for more reliable analyses as to whether different components of EF play different roles in children's repair behaviour. Of course, these decisions are often heavily guided by logistical constraints, such as increasing the experimental time and participant fatigue.

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Other considerations relate to our study design, such as including a within-subject design, which may have created carry-over effects from one feedback type to another (despite our inclusion of filler trials where feedback was not needed). As well, as is the case for many referential communication studies, it is unclear whether the task itself adequately reflects children's everyday communicative contexts. For instance, children's motivation needs to be taken into account as, while there was a clear goal (to help the listener find the prize), the reasons for doing so were not made clear and it is possible that motivational factors may have played a role in children's performance (Varghese & Nilsen, 2013). Further, subtle aspects to the task design can influence children's performance. One aspect we noted earlier was that children were informed that they could provide additional information across the feedback conditions (as pilot testing suggested they did not know this was allowed), which may have reduced differences across the conditions. A limitation to note is the sample size. Having a larger sample may result in a greater ability to detect any potential effect of nonverbal feedback, which may be small. In addition, due to COVID-19 restrictions, the study had to be moved online rather than in-person. Notably, we found that the testing environment was not a significant predictor of any of our outcome variables in this study. However, there are some limitations to conducting research online. For instance, while moving the study online increased the geographic range from which we could recruit, it likely reduced the diversity of our sample (e.g., only families with a computer or iPad were able to participate).

Conclusion

Overall, findings highlight 4- and 5-year-old children's ability to detect that their message was unclear and repair statements in response to feedback from a listener. Children were found to repair their messages more frequently in response to verbal feedback compared to

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nonverbal feedback. Adding nonverbal cues to verbal feedback appeared to have no greater benefit for repairs compared to receiving verbal feedback alone. Children also demonstrated the ability to repair their messages in response to a listener pause and demonstrated that they learned to provide more effective messages across trials. The present study supports the notion that EF is important for children's initial message production, as well as for repair behaviours, most notably children's working memory skills. The precise nature of the association between EF and communicative repairs is difficult to disentangle due to different methodological decisions across studies, for both communicative and EF tasks. In this study we presented various types of feedback within the same design to improve upon this. However, as more studies emerge in the area of children's communicative repairs there are increased opportunities to compare and contrast the role that EF and EK play under different conditions.

General Discussion

The aim of the two studies reported here was to investigate children's ability to use affective cues to guide their communicative behaviors. Together, the studies demonstrate that 4- and 5-year-old children can detect and repair their miscommunications in response to nonverbal cues and that verbal feedback is superior to nonverbal feedback in supporting children's communication repair. Findings also highlight the important role that emotion knowledge and executive functioning play in children's communication.

Summary of Results

Children's Ability to use Affective Cues to Guide their Communication

Study 1 demonstrated children's ability to detect miscommunication and repair their messages in response to the downstream effects of their communication; that is, whether or not a listener found a prize after following their instructions. Based on the quality of children's instructions, the listener either appeared happy and presumably found the prize, or appeared sad and presumably failed to find the prize. Findings revealed that children had accurate perceptions of their communication after receiving only nonverbal feedback from the listener. That is, they were able to effectively determine whether or not the listener found the prize based solely on her facial expression. They were also able to recognize their role in the success of each trial and rated their skills as speakers higher on trials where the listener appeared happy. Children were also found to rate the listener's skill as being lower on trials where she appeared sad, suggesting that they somewhat blame the listener for the miscommunication even when the listener was actually not at fault. I also assessed children's likelihood of attempting to repair their messages following miscommunication. Findings revealed that children were more likely to attempt to repair their message after seeing the listener look sad (albeit often producing unsuccessful

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repairs). Children also demonstrated improved initial messages across trials, suggesting that they learned from the nonverbal feedback to improve their effectiveness as speakers.

In Study 2, children were provided with different types of feedback from the listener when they provided ambiguous instructions. On each trial, they either received baseline feedback (i.e., a listener pause), verbal feedback (i.e., the listener saying "I don't know which one you mean"), nonverbal feedback (i.e., the listener making a confused facial expression), or both verbal and nonverbal feedback simultaneously. Results demonstrated that children often repaired their messages even in response to very subtle listener cues, such as a pause. Further, verbal feedback indicating the child had been misunderstood led to more repairs than the baseline condition, where the listener paused. Nonverbal feedback (i.e., a confused facial expression) did not yield more repairs than the baseline condition. In addition, there was no benefit to receiving both verbal and nonverbal feedback simultaneously compared to just receiving verbal feedback alone. As in Study 1, children's initial messages improved across trials indicating that they learned from the feedback provided.

Together, the two studies suggest that children use nonverbal cues from a communicative partner to guide their communication. Study 1 demonstrated that children were able to recognize when miscommunication occurred in response to the listener's happy or sad facial expression. While Study 2 did not find a benefit of nonverbal feedback compared to the baseline condition, children attempted to repair at a high rate (56%) even in the baseline condition. This suggests they were picking up on subtle nonverbal cues indicating confusion, such as a listener pause. Notably, adding further nonverbal cues (i.e., a confused facial expression) to a pause did not result in more repair behavior. The findings of Study 2 indicate that verbal feedback is superior to nonverbal feedback in eliciting communication repair.

The Role of Executive Functioning in Children's Communication

The findings also highlight the role of executive functioning in children's ability to detect and repair miscommunication. The results of Study 1 revealed that children's executive functioning skills (as represented by a latent variable) were related to their ability to discern whether or not the listener had found a prize based on the nonverbal cues she provided. That is, children with better executive functioning skills were more accurate in their ratings as to whether or not the listener found the prize based on her facial expression. Children with stronger executive functioning were also more accurate in their ratings of their own skill as speakers. That is, they were more likely to rate themselves poorly on trials where the listener appeared sad, and well on trials where the listener appeared happy. Children with stronger executive functioning also rated themselves as being better speakers overall, regardless of the facial expression of the listener. While executive functioning was found to be related to children's detection of miscommunication, it was not related to children's repair behavior. That is, there was no relationship between executive functioning and children's likelihood of deciding to repair their messages. In Study 1, executive functioning was also not found to relate to the quality of children's initial messages or repair messages.

In Study 2, I examined the relations between each component of executive functioning and children's communicative behaviour separately because each component did not load onto a single factor in this sample. The difference in ability to create the latent variable between studies may be due to data collection: the majority of data for Study 2 was collected online rather than in person (Study 1 was conducted in person). When examined individually, working memory and cognitive flexibility were significant predictors of the quality of children's initial messages. Inhibition was not found to predict the quality of children's initial messages. When cognitive

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flexibility, inhibition, working memory, and expressive vocabulary were put together in one model, the effects of working memory and cognitive flexibility were marginally significant. When working memory was included within a model on its own, it was also a significant predictor of children's likelihood of attempting a repair, while cognitive flexibility and inhibition were not significant predictors. When all three components of executive functioning were included in one model, I found that none of the components were significant predictors of children's likelihood of repairing their messages. This may be due to there being a lower sample size (i.e., of participants who completed all executive functioning tasks), and thus lower power, compared to when working memory was analyzed in a model on its own. Finally, working memory was a significant predictor of the number of new descriptors children provided during repairs, but inhibition and cognitive flexibility were not. When all three components of executive functioning were included in a model together, working memory remained a significant predictor of the quality of children's repair messages.

For comparison, I also re-analyzed the data from Study 1 to examine the role of individual components of executive functioning in children's repair behaviour. I found that in Study 1, the results were consistent with the latent variable, namely, there was not a significant association between any executive functioning components and children's repair behavior.

In summary, the findings of Study 1 and 2 demonstrate that executive functioning skills are important for detecting miscommunication. The role of executive functioning in children's repair behavior is less clear, with some evidence suggesting that working memory plays a role in children's decision to repair their messages and in the quality of children's repairs. The role of executive functioning in children's ability to produce effective initial statements is also mixed,

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with the results of Study 1 finding no association between executive functioning and the quality of initial statements, and Study 2 finding a significant association.

The Role of Emotion Knowledge in Children's Communication

As this work assessed children's responses to affective listener cues, I also examined the role of emotion knowledge in children's communication. In Study 1, emotion knowledge appeared to play a similar role to that of executive functioning. That is, children with stronger emotion knowledge were more accurate in their determinations of whether or not the listener found a prize and were also more accurate in their ratings of themselves as speakers. Children with stronger emotion knowledge also rated their own skills as speakers as being higher overall, regardless of the facial expression of the listener. In addition, children with stronger emotion knowledge skills rated the listener as being more effective overall compared to those with weaker emotion knowledge skills. In Study 1, while executive functioning was not associated with children's tendency to repair their messages, emotion knowledge was. Children with stronger emotion knowledge were more likely than those with weaker emotion knowledge to repair their messages when the listener looked sad. In Study 1, emotion knowledge was not found to associate with the quality of children's initial messages, or with the quality of their repair statements. However, in Study 2, children with stronger emotion knowledge produced more effective initial messages and produced more detailed repair statements than those with weaker emotion knowledge. Also, in contrast to the results of Study 1, Study 2 found that emotion knowledge was not associated with children's likelihood of repairing their messages. Emotion knowledge was associated with children's ability to produce effective initial messages in Study 2, but not in Study 1.

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Overall, findings suggest that emotion knowledge is important for children's communication repair (with mixed results for the production of initial statements), although the specific role that emotion knowledge played in each study differed.

Implications of Findings

Theoretical Implications

Children's Ability to use Affective Cues to Guide their Communication. Past work suggests that 2- to 7-year-old children detect nonverbal cues from others they are interacting with and use this information to guide their behavior. For instance, Birch and colleagues (2010) found that 2- and 3-year-old children picked up on cues of uncertainty in others, and trusted individuals who appeared uncertain less than those who appeared more confident. Wardlow and Heyman (2016) also demonstrated that children learned across trials to provide more effective referential statements when provided with nonverbal feedback (i.e., a confused facial expression, and the confederate choosing the incorrect object) indicating their messages had been misunderstood. Thus, across various contexts, children demonstrate behaviors indicative of monitoring and making use of nonverbal information from others. What was not known prior to the two studies reported here is the degree to which children can make use of affective feedback from their communicative partner to guide their detection and repair of miscommunication.

My work extends previous findings demonstrating children's ability to repair their messages in response to verbal feedback provided by the listener (e.g., Bacso & Nilsen, 2017; Coon et al., 1982; Deutsch & Pechmann, 1982; Nilsen & Mangal, 2013; Uzundag & Küntay, 2018). Specifically, the studies reported here are the first to investigate children's ability to detect and repair miscommunications in response to nonverbal, affective cues from a listener. Findings revealed that children were able to detect miscommunications, based on their ratings,

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after seeing the listener appear sad in Study 1. Children were also more likely to repair their messages when the listener appeared sad. This suggests that children are in fact using affective cues to guide their detection and repair of miscommunication. The findings reported in Study 2 revealed that while children were able to repair their messages in response to nonverbal feedback from the listener (i.e., they even repaired their messages in response to the listener pausing), they were more likely to detect and repair miscommunications following verbal feedback. Overall, my work adds to the literature on the ways children detect and use affective cues by showing this process within the act of communicative repair.

Socio-Cognitive Skills Associated with Children's Communication. Several researchers have theorized that executive functioning would play a role in children's communication. For instance, Nilsen and Fecica (2011) proposed that executive functioning plays a role in children's communication by supporting their ability to make use of the perspective of their communicative partner to guide their communication. Davies and Kreysa (2018) suggested that executive functioning may facilitate children's ability to make use of information gleaned from looking at a contrast object (i.e., what dimensions are the same as or different from the target object) in order to provide an effective description of the target object during referential communication. Further, Volden (2004) proposed that working memory would be involved in children's ability to hold information in mind about a listener's knowledge state, and their feedback while formulating repair messages. Volden also proposed that cognitive flexibility may be involved in communication repair since this would involve flexibly shifting the way one had initially described the target. Evidence from past research supports the idea that executive functioning skills are important for children's communication skills, but the exact mechanisms through which executive functioning skills are involved remain unclear.

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As was discussed in the General Introduction, children's executive functioning skills have been demonstrated in research to play a role in their communication skills. The two studies reported here provide partial support that executive functioning plays a role in both the production of effective initial messages and children's ability to detect and repair miscommunications based on verbal and nonverbal cues provided by the listener. Notably, executive functioning was only found to relate to the quality of children's initial messages in Study 2 (i.e., working memory and cognitive flexibility), and not in Study 1. Executive functioning appears to be clearly related to children's ability to detect miscommunication, and to reflect on the quality of their own messages, as evidenced by the association with executive functioning and children's success ratings and self-ratings in Study 1.

In contrast to past work, which found that cognitive flexibility was associated with children's repair behavior (Bacso & Nilsen, 2017; Uzundag & Küntay, 2018), only working memory was found to relate to children's repair behavior in Study 2, and there was no association between a latent variable of executive functioning and children's repair behavior in Study 1. These differences in findings may be attributed to methodological differences across studies. Overall, the findings are mixed, but provide some evidence for a role of working memory in children's communication repair.

The exact mechanisms through which executive functioning supports communication remain unclear. In my past work, we proposed that cognitive flexibility facilitated communication repair by allowing children to view the dimensions of the target more flexibly and shift the way they described the target during a repair (Bacso & Nilsen, 2017). Working memory may play a role by allowing children to hold their original message and the listener's feedback in mind while deciding to repair and formulating a response as per Volden (2004).

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Executive functioning may play a role in children's initial messages by helping children to integrate the feedback they receive into their subsequent initial messages (as suggested by Wardlow & Heyman, 2016). This may explain the association between executive functioning and the quality of children's messages in Study 2 but not in Study 1, since Study 2 provided children with more explicit feedback indicating they had been misunderstood. Further research will be needed to test these theories as to how exactly executive functioning supports children's communication skills.

While there is an extensive literature on the role of emotion knowledge for children's social skills (e.g., Bassett et al., 2012; Denham et al., 1990), my work is the first demonstrating the importance of this skill for communication, and more specifically for communicative repair. These findings also expand on the findings of Khu and colleagues (2017), who found a relationship between emotion knowledge and children's ability to use a speaker's emotional prosody to guide their interpretation of messages, by demonstrating that emotion knowledge plays a role in other types of communicative behavior. Findings demonstrate that emotion knowledge is important for children's initial production of messages (Study 2), for their detection of miscommunication (Study 1), and for their ability to effectively repair their messages (Studies 1 and 2). Interestingly, emotion knowledge was associated with children's repair behavior following all feedback types in Study 2, which suggests that emotion knowledge is important for more than just picking up on nonverbal cues provided by the listener. It may be the case that children with stronger emotion knowledge are more likely to be attuned to the needs of the listener, which aids in their ability to detect miscommunication and to provide informative repair messages.

Research Implications

This work has implications for the design of research studies looking at children's communication, and for the measurement and representation of executive functioning in children.

Methodological Implications. A challenge that exists in the literature on children's communication skills is that subtle changes in the methodology of a study can have a significant impact on children's communicative behavior, making it difficult to compare results across studies. As such, the results of any study on children's communication must be interpreted within the demands of the task itself. The communicative task for this work was intended to be difficult for children in order to elicit a greater number of ambiguous initial messages, which needed repair. As such, within our communication task, miscommunications were probably more frequent than they typically are in a child's everyday life. The communicative task could be made easier for children by reducing the number of objects in the array, or by reducing the number of descriptors needed to uniquely identify the target (as in Nadig & Sedivy, 2002). Our array included 7 objects, and children were required to provide 2 descriptors in addition to the object name to uniquely identify the target. In past work with a similar array size and number of attributes to be described (e.g, Lloyd et al., 1998), children ages 4 to 6 have typically failed to produce effective messages for their listeners.

The type of feedback provided by the listener has also been found to have a significant impact on children's repair strategies (Bacso & Nilsen, 2017; Coon et al., 1982). This is of particular relevance for Study 2, where I compared the effects of several different types of listener feedback. We decided to give children vague verbal feedback (i.e., "I don't know which one you mean.") rather than more detailed verbal feedback (i.e., "there are three boys and I don't

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know which one you mean.”) This decision was made to more closely equate the level of detail provided in the verbal feedback and nonverbal feedback conditions. However, had we provided participants with detailed feedback, this may have increased the effects of the verbal feedback condition on children's repair behavior. We also decided to make the baseline condition contain a listener pause, which children appear to have interpreted as listener confusion since they repaired their messages in response to this feedback. Had we made it so that the listener immediately chose a box in the baseline condition, our findings may have been different, perhaps with nonverbal feedback (i.e., a confused facial expression) appearing to have a stronger effect on children's tendency to repair their messages.

Across studies, the feedback provided by the listener has varied, making comparisons difficult. For instance, Deutsch & Pechmann (1982) repeated back participants' initial ambiguous descriptions to the listener in a question format (i.e., if the child said, “big ball”, the listener would say, “which big ball?”). If children provided another ambiguous message, their instructions were again repeated back in a question format. This led to a high rate of successful repairs, with even 3-year-olds being able to successfully repair their messages on 89% of trials.⁸ Other researchers have had the listener choose the incorrect object in response to a child's ambiguous message (Nilsen & Mangal, 2012; Wardlow & Heyman, 2016) or provided children with verbal feedback that varies in the level of detail provided (Bacso & Nilsen, 2017; Coon et al., 1982; Deutsch & Pechmann, 1982; Nilsen & Mangal, 2013; Uzundag & Küntay, 2018). Although this variability in the feedback provided to children by their listeners makes direct comparisons across studies difficult, it does provide important information on the types of feedback that may be most effective in eliciting communication repair.

⁸ Participants were able to successfully repair their message on 15% of trials in Study 1 and 31% of trials in Study 2.

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Additionally, children's level of motivation to communicate effectively may vary across studies. Varghese and Nilsen (2013) demonstrated that motivational factors impacted children's performance on a referential communication task. Specifically, they found that allowing school-age children (ages 6 to 8) to take home stickers that they described effectively led to them producing more detailed descriptions of the target stickers compared to a condition where they were not promised stickers to take home. Notably, this effect was not seen for preschool-age children (ages 3 to 5), which may reflect their inability to monitor and adjust the clarity of their messages. In the present study, children's motivation to provide effective messages was to help the listener to find a prize, but they themselves did not receive any rewards for doing so effectively. It is possible that giving children rewards for successfully describing the target would have increased their effectiveness in describing the target. Motivational factors vary widely across studies, with some studies offering participants rewards (e.g., Matthews et al., 2007) and others not offering any incentives (e.g., Nadig & Sedivy, 2002). As such, motivational factors should also be considered when interpreting the findings of any given study.

In summary, differences in study design, variations in listener feedback, and motivational factors will all impact the findings of any given study. Because of this, findings should be interpreted within the demands of the task included in each study. Because of methodological differences across studies, it is difficult to determine a developmental trajectory for children's communication skills. However, despite differences across studies patterns still emerge which allow for some conclusions to be made. Looking at differences in findings across studies using a variety of methodologies can also provide researchers with information on the various factors that impact children's communicative performance. A challenge for the field will be to establish

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more consistent ways of studying children's communication skills so that developmental trajectories can be mapped out.

Implications for the Measurement of Executive Functioning. A challenge within the literature on children's executive functioning skills is that there is no universal agreement on the number of identified executive functioning factors (see Karr et al., 2018), making determinations about how to model executive functioning quite difficult. In the preschool years, researchers have proposed either a 1-factor (Brocki & Bohlin, 2004; Hughes et al., 2010; Nilsen et al., 2016; Weibe et al., 2011) or 2-factor (Miller et al., 2012; Müller & Kerns, 2015) model of executive functioning. In Study 1, we used a one-factor model of executive functioning. In Study 2, we attempted to create a one-factor model of executive functioning but found that the factor loadings for each component of executive functioning were non-significant, suggesting that the executive functioning tasks did not converge onto one factor for the sample used for Study 2. As noted previously, this may be because most of the data for Study 2 was collected online, whereas data for Study 1 was collected in person. Since the factor loadings were non-significant, we decided to perform separate analyses for each component of executive functioning (i.e., working memory, cognitive flexibility, and inhibition) in Study 2 rather than using a latent variable. We also created models which included all three components of executive functioning together in order to determine the unique contributions of each component of executive functioning, controlling for other components.

Studies investigating the role of executive functioning in communication have used different ways of measuring executive functioning and different ways of representing executive functioning in analyses, making comparisons across studies difficult. The most common way of representing executive functioning in the literature on children's communication is to use

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individual components of executive functioning, such as working memory, cognitive flexibility, and inhibition (Bacso & Nilsen, 2017; Nilsen & Graham, 2009; Uzundag & Küntay, 2018; Wardlow & Heyman, 2016). This approach can be problematic because tasks used to measure executive functioning vary widely across studies, and factors other than executive functioning would impact children's performance on the tasks used (e.g., attention, processing speed, general intelligence, etc.). Some tasks used to assess executive functioning also have low reliability (see Hedge et al., 2017), which makes them ill-suited for correlational research because this makes it difficult to detect relationships with other constructs. By using a latent variable to represent executive functioning in Study 1, there was the benefit of reducing task-specific variance and measurement error (Kaushanskaya et al., 2017; Tabachnick & Fidell, 2013). Latent variables of executive functioning have also been used in other related areas of research, such as in exploring the role of executive functioning deficits in the social problems experienced by children with ADHD (Huang-Pollock, Mikami et al., 2009) or ASD (Jones et al., 2018). Further, existing studies support using a latent variable to measure executive functioning in adults (Miyake et al., 2000), and young children (Fuhs et al., 2014; Willoughby et al., 2012).

Results may also differ based on the way executive functioning is represented in analyses. Work by Camerota and colleagues (2020) demonstrates how the representation of executive functioning can impact the findings and conclusions researchers draw from their studies (also see Rhemtulla et al., 2020 for a similar demonstration). Camerota and colleagues analyzed their dataset using both a latent variable of executive functioning, and a composite variable of executive functioning and found differing results. The researchers caution against universally using latent variables to represent executive functioning. Reasons behind this include that the correlations between executive functioning measures are typically quite low, (with

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correlations around $r = .2$ to $.4$)⁹. Because of this, there is little shared variance left to define the executive functioning construct in a latent variable. Further, the shared variance between executive functioning tasks could represent other shared variation besides variation in executive functioning, such as general intelligence. However, composite variables also have problems: for instance, they have no error term, and thus do not account for measurement error. Further, since correlations between executive functioning tasks are low, composite variables may also have poor validity in comparison to latent variables (i.e., they may be a poor indicator of the construct that one is trying to measure). Camerota and colleagues recommend that researchers pay attention to the measurement models used in various studies and recognize that the results of studies may vary based on the measurement model used. They also recommend comparing results while using different measurement models (i.e., composite variables versus latent variables), and noting any differences in findings.

Together, my work in combination with the existing literature (Camerota et al., 2020, Rhemtulla et al., 2020) suggest that researchers should pay careful consideration to the type of measurement model they will use to represent executive functioning. Differences in the way executive functioning is represented (i.e., individual components, composite variables, or latent variables) can likely account for some of the differences in results seen across the executive functioning literature. Unfortunately, there is no statistical test that can be used to determine which measurement model would be best to represent executive functioning so researchers must use their own judgement to determine how they will represent executive functioning in their research. Future work is needed to identify “best-practices” for studying individual differences in executive functioning, including an agreed-upon model or approach to executive functioning.

⁹ In my Study 1 and Study 2 correlations between executive functioning tasks ranged from $r = .05$ to $.32$.

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Having a consistent model that is widely used would allow for comparisons to be made more easily across studies.

Researchers should use theory and be guided by their research questions when making decisions about how to model executive functioning. If a researcher views executive functioning as an unobservable construct that we can use a variety of tasks to measure, then using a latent variable of executive functioning may make the most sense. Using a latent variable should provide the 'purest' representation of executive functioning possible. However, some researchers may be interested in looking at one particular component of executive functioning. Ideally in this circumstance, they would use multiple indicators of the component being studied and create a latent variable of that component (e.g., a working memory latent variable). There may also be cases where a researcher is interested in looking at relationships between a particular executive functioning task and other constructs. For instance, Bardikoff and Sabbagh (2021) were interested in whether training children on a specific aspect of a commonly used cognitive flexibility measure, the Dimensional Change Card Sort (DCCS) task, would lead to improvements in their scores on this particular task. In this case, it made sense for them to use a single indicator of cognitive flexibility, since they were interested in that task in particular. Practical factors, such as length of testing session, likely also come into play. For example, researchers may only be able to measure one component of executive functioning due to time constraints and thus would be unable to compute a latent variable.

The developmental stage of a child should also be considered when making decisions about how to represent executive functioning. Karr and colleagues (2018) found that executive functioning becomes more differentiated as children develop. In early childhood it has a one-factor or two-factor structure, and eventually develops into having a three-factor structure.

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Therefore, if using a latent variable to represent executive functioning, researchers could look to the literature to determine how many factors of executive functioning should be represented.

Lastly, the decision to use a latent variable or look at individual components of executive functioning also depends on how well one's data fits with the proposed model of executive functioning. For instance, in Study 2 we attempted to create a 1-factor latent variable of executive functioning but found that factor loadings were non-significant. If we were to go ahead with using this latent variable, it would be unclear what exactly our latent variable was measuring. That is, our latent variable would not have been a good representation of executive functioning. In this case, it made more sense to use individual components of executive functioning for analyses rather than using a latent variable.

Practical Implications

The findings of the two studies reported here also have practical implications for the development of children's communication skills. In particular, the findings suggest that what a listener does or says in response to a child's communicative attempts is important for their subsequent behavior. In particular, the findings from each study suggest that children make use of both verbal and nonverbal feedback provided by their listeners during communication. Findings also suggest that using nonverbal and verbal feedback from caregivers, peers, and other conversational partners is an important way through which children develop into effective speakers over time. This means that caregivers should aim to provide young children (approximately ages 3 to 6) with feedback when they provide ambiguous messages to support their communicative development. Based on the results of the present work, and my past work (Bacso & Nilsen, 2017), feedback provided to children is most effective at eliciting repairs when it is verbal, and more detailed. Ideally, feedback should provide explicit information about what

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was missing in children's initial statement. Providing children with explicit feedback is likely to result in more effective communication in the moment, and to aid in children's development as speakers over time.

Findings also demonstrate the importance of executive functioning and emotion knowledge for children's communication skills. This suggests that children who struggle with executive functioning or emotion knowledge are likely to develop difficulties with their communication skills as well, and that assessment of children's executive functioning and emotion knowledge skills could help to flag children who are likely to fall behind in their communicative skills. Such early identification of children who may develop communicative difficulties would allow for targeted interventions to improve children's communication skills. These interventions could focus directly on children's communication skills, on their executive functioning skills, or on their emotion knowledge skills.

As was discussed in the General Introduction, previous work has shown that allowing children the opportunity to repair their messages leads to improvements in their ability to produce effective messages over time (Matthews et al., 2007; Matthews et al., 2012). This suggests that practicing communication repair may be an effective intervention to improve children's skills as speakers. More research is needed to determine whether interventions targeted on children's communication repair would also lead to improvements in other areas of communication, such as children's ability to effectively comprehend messages from a speaker.

The findings of the two studies reported here also demonstrate how specific aspects of children's communication relate to their emotion knowledge and executive functioning skills. When determining what type of intervention would be most effective for a child it is important to identify particular challenges in their communication skills and look to the existing research to

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determine what cognitive skills may support that particular communication skill. For instance, if during a referential communication task, a child is looking at the listener's facial expression, but not responding appropriately they may need intervention related to emotion knowledge. If a child appears to be scanning the target and distractors, but is still not producing an effective referential message, then intervention may need to focus on their executive functioning skills. Breaking down communication into its components and identifying the cognitive skills that support each aspect of communication is therefore important for designing interventions.

Since executive functioning was found to be associated with children's communication skills, interventions targeted at improving children's executive functioning skills may also lead to improvements in their communication skills. It is generally agreed that executive functioning training programs are effective in improving performance on tasks similar to the tasks used during the training (near transfer), but there is not a strong consensus as to whether these training programs lead to far transfer of untrained tasks, such as leading to improvements in academic performance (see Smid et al., 2020 for a review). Gunzenhauser and Nückles (2021) have proposed that executive functioning training could lead to improvements in academic skills if training programs occur in authentic contexts, such as in supporting children in creating a plan and monitoring the steps involved.

No studies have examined the effectiveness of executive functioning training for improving children's communication skills but based on mixed support in the existing literature for executive functioning training having far transfer effects, it seems unlikely that executive functioning training would improve children's communication skills. It is possible that recommendations similar to those proposed by Gunzenhauser and Nückles for academic performance could facilitate the transfer of executive functioning training to children's

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communication skills. That is, interventions could explicitly have children practice executive functioning in the context of communication, such as practicing holding a listener's feedback in mind while formulating a response.

Training specific aspects of executive functioning that seem particularly relevant for children's communication skills may also be effective. For instance, Bardikoff and Sabbagh (2021) found that having 3-year-olds play a game where they separated and aggregated objects based on the objects' color and shape led to improvements in their cognitive flexibility. As was previously noted, the ability to think flexibly about a target's dimensions appears to be particularly important for referential communication tasks. Therefore, it is possible that training this specific aspect of cognitive flexibility could lead to improvements in children's referential communication, although future work is needed.

Another possible area of intervention is in targeting children's emotion knowledge skills. A number of training programs have targeted children's emotion knowledge skills and have demonstrated improvement in these skills (Izard et al., 2008; Ornaghi et al., 2017; Richard et al., 2020; Whitcomb & Merrell, 2012). Notably, while past research has shown that emotion knowledge training can lead to improvement in children's broader social skills (Izard et al., 2008; Ornaghi et al., 2017), no research has explored the impact of emotion knowledge training on children's communication skills. However, given the robust literature on associations between children's emotion knowledge and their social competence (e.g., Bassett et al., 2012; Denham et al., 1990), emotion knowledge appears to be a good target for interventions intended to improve children's communication skills.

Conclusions

As discussed in the General Introduction, limited work has explored children's ability to detect miscommunication and repair their messages in response to nonverbal cues from the listener, and no studies have explored the socio-cognitive skills involved in this process. My research adds to the literature by demonstrating that children use nonverbal cues to guide their communicative behavior. However, while children can use nonverbal cues to determine when their messages are misunderstood and are in need of repair, they are more readily able to recognize miscommunication and repair their messages following verbal feedback. Findings also highlight that emotion knowledge supports children's ability to recognize miscommunication, and to effectively repair miscommunication. Executive functioning as measured by a latent variable appears to be involved in children's ability to detect miscommunication and working memory appears to be associated with children's ability to repair their messages. Thus, just as an effective dancer will adjust their movements to account for their partner's misstep, children demonstrate the ability to use subtle cues from their communicative partners to guide their production and repair of messages such that communication is more (albeit not uniformly) successful.

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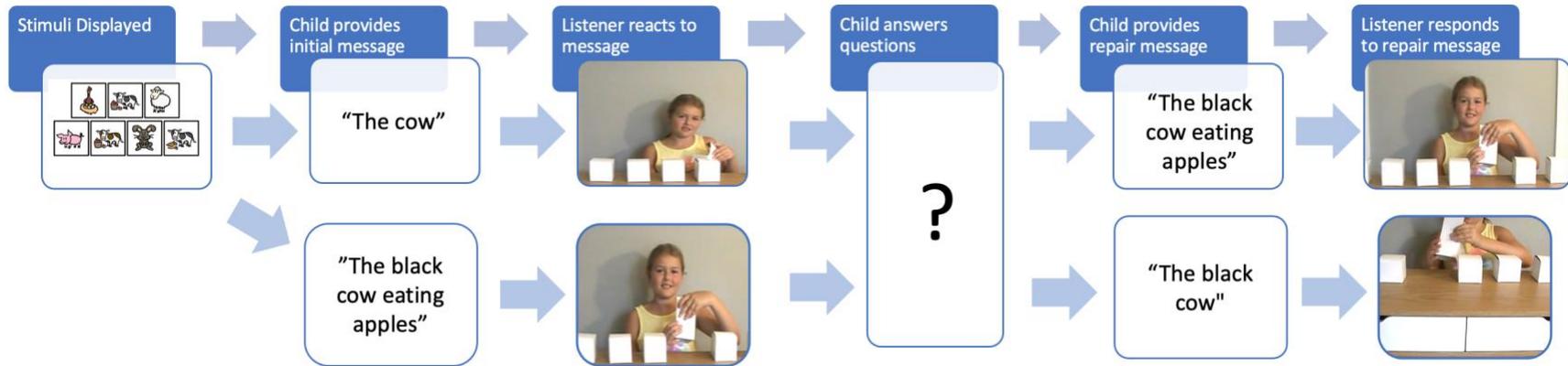
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Appendices

Appendix A

Flow chart illustrating the procedures for test trials of the communication task in Study 1.



Appendix B

Items included in the communication task for Study 1. Note that items were presented in one of three possible orders for counterbalancing and the same array of boxes was used for both a simple and a complex trial. Key descriptors for complex trials are bolded. Key distractor items for complex trials are in italics.

Target object on complex trial	Target object on simple trial	Distractors
Red clown juggling or with balls	Lion	<i>Blue clown juggling, red clown holding balloons, horse with feathers on its head, seal with a ball, elephant on a platform, lion on a platform</i>
Boy wearing red holding an ice cream	Dog	<i>Boy wearing green holding an ice cream, boy wearing red holding a drink, girl on a bench, man holding ice cream, dog with a bone, cat with a mouse</i>
Brown monkey holding a banana	Tiger	<i>Black monkey holding a banana, brown monkey holding a flower, tiger with a leaf, hippo with a flower, giraffe with a ball, toucan with bananas</i>

Appendix C

Flow chart illustrating the procedures for test trials of the communication task in Study 2.

