Development of audience design in adolescents' reference production

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Abstract

Compared to adults, children are less effective at designing their utterances to suit the informational needs of their audience. This listener-catering behaviour, known as audience design, has been hypothesized to rely on domain general cognitive mechanisms, such as working memory and cognitive flexibility. Considering that adolescence is an important period of sociocognitive growth, research on the development of audience design beyond childhood is surprisingly scant. The aim of this study was to trace the development of audience design in early and middle adolescence, and test its reliance on cognitive control function. Participants (11–12 and 15–16 years) performed two tasks assessing (1) the ability to adjust referential expressions to inferred knowledge of hearers and (2) cognitive control function. The findings suggest that the ability to take into account the informational needs of listeners during utterance formation develops considerably between early and middle adolescence. Although performance on both tasks was higher in the middle adolescent group, the study provides no evidence for a reliance of the measured audience design behaviour on cognitive control function. Future research should aim to determine whether the development of audience design in adolescence is facilitated by an increased efficacy of knowledge state attribution processes.

Keywords

Utveckling av mottagaranpassning i ungdomars referentproduktion

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Sammanfattning

Förmågan att anpassa sina yttranden efter samtalspartnerns behov är mindre utvecklad hos barn än hos vuxna. Beteendet att ackommodera lyssnaren vid yttrandeformulering benämns ofta som mottargaranpassning. Mottagaranpassning i konversation har föreslagits vara avhängig exekutiva funktioner, såsom arbetsminne och kognitiv flexibilitet. Med tanke på att ungdomsåren är en viktig period för social och kognitiv mognad har anmärkningsvärt lite forskning genomförts på utvecklingen av mottagaranpassning under ungdomsåren. Målet med studien var att undersöka utvecklingen av mottagaranpassning i ungdomsåren och testa dess eventuella avhängighet av exekutiva funktioner. Deltagare (11–12 och 15–16 år) genomförde två tester som mätte (1) förmågan att anpassa referentiella yttranden till lyssnares förmodade omvärldskunskap och (2) exekutiva funktioner. Resultaten indikerar att förmågan att anpassa sina yttranden efter lyssnares förmodade omvärldskunskap utvecklas betydligt under ungdomsåren. Trots att den äldre åldersgruppen presterade bättre på testet som mätte exekutiva funktioner, predicerade inte exekutiva funktioner förmågan att mottagaranpassa referentiella yttranden. Framtida studier bör undersöka huruvida förmågan att tillskriva kunskapstillstånd till andra effektiviseras under ungdomsåren, och således främjar utvecklingen av mottagaranpassning.

Nyckelord

Mottagaranpassning, pragmatisk utveckling, referentiell kommunikation, ungdomar.

Contents

1   Introduction

When participating in conversation, speakers are continuously faced with the task of adapting their utterances in accordance with the specific needs of interlocutors. This communicative perspective-taking during online [1] language production is termed *audience design* (AD) (Clark and Murphy, 1982), alternatively *recipient design* (Sacks and Schegloff, 1979). Models of AD involve listener-catered adjustments that operate on all levels of language (Ferreira, 2019). This can, for instance, translate to style-shifting (Bell, 1984), the adding and omitting of confusion reducing content (such as case markings) (Kurumada and Jaeger, 2015), or the modification of acoustic features in the speech signal (e.g. reduction vs. prominence) (Arnold et al., 2012). One of the most salient listener-catering behaviours is the tendency to be particularly informative towards audiences that are assessed to need additional information to understand, such as novices (Isaacs and Clark, 1987) or children (Tippenhauer et al., 2020). In reference production, speakers who provide the information necessary to prevent miscommunication adjust their referential expressions in accordance with the knowledge state of their listener. For example, a speaker addressing an audience that is assumed to have no knowledge of Swedish politicians may choose to utter 'The prime minister of Sweden', over 'Stefan Löfven', in order to increase the possibility of being understood by that particular audience.

Although children as young as 3–4 years old are aware that others' knowledge states can differ from their own (Perner and Leekam, 1986), 5– to 6-year-olds fail at using information about listeners' knowledge states in referential production tasks (Nadig and Sedivy, 2002). In consequence, it has been suggested that the ability to use information regarding one's listener's knowledge during online communication demands cognitive effort, and thus relies on domain general cognitive control functions (CCF) [2] (Nilsen and Fecica, 2011). However, the validity of traditional paradigms for measuring AD have been called into question, since optimal performance on these tasks can be reached by using visual selective attention alone (Rubio-Fernández, 2017). Considering that the ability to engage in communicative perspective-taking affects the well-being of adolescents (Nilsen and Bacso, 2017), research on the development of AD in adolescence is surprisingly scarce. This essay aims to address the gap in the literature by tracing the development of AD in reference production and investigate its reliance on CCF in early and mid adolescence, using an innovative design (Bentdz et al., 2020) that requires speakers to consider the knowledge states of listeners to produce perspective-appropriate referential expressions.

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[1]The term 'online' denotes the actual time under which a given process takes place.
[2]CCF is here used as a term interchangeable with executive function.

2 Background

2.1 Audience design in reference production

In every day dialogue, speakers often tailor their utterances to suit the informational needs of their audience. This listener-catering behaviour is termed *Audience Design* (AD). Consider the following exchange by two teenagers, overheard at an underground station in central Stockholm:

A: that guy added me on snapchat
B: who?
A: that guy we met at Gabriel's place
B: aha
B: I think his name is Johan

In this exchange, A makes two attempts at referring to Johan. The first attempt is insufficient since it does not establish Johan's identity, whereas the second attempt does. To most individuals, the referential expression in the second attempt is as ambiguous as the first; only a restricted number of people are aware under what circumstances the two teenagers met Johan. B, however, shares the knowledge needed to successfully interpret her conversational partner's reference – A's second attempt is adequate because B is the addressee. Because of the simplicity and pervasiveness of referential communication (Asher, 1979), reference has received substantial attention within AD research. This thesis is concerned with AD in reference production.

Speakers that employ AD adhere to Grice's (1975) *Cooperative Principle*. Namely, they expect their utterances to be adequately informative, relevant and explicit in its particular context. In regards to reference production, the *Maxim of Quantity* is perhaps the most applicable one (p.45):

1. Make your contribution as informative as required.

2. Do not make your contribution more informative than is required.

The Cooperative Principle and the Maxim of Quantity state that speakers are expected to adjust the informativeness of their utterances in commensurate with the informational needs of the hearer. This includes not being overly informative. As an illustration, consider a situation in which a speaker produces the referential expression 'my oldest child'. If the speaker is talking to a close family member, her referential expression is probably too informative. Conversely, if she is talking to a stranger, 'Erik' provides too little information. AD entails providing the ideal amount of information in a given communicative context. Clark et al. (1983) labels the optimal informativeness of referential expressions the *Principle of optimal design*.

AD requires the speaker's ability to distinguish between what is common ground (knowledge shared by the interlocutor) (Clark and Murphy, 1982), and what is privileged ground (knowledge exclusively available to the speaker) (Horton and Keysar, 1996). According to Clark and Murphy (1982), common ground is accessed through a set of heuristics, including *linguistic co-presence* (whether the referent has previously been mentioned in the discourse context), *physical co-presence* (whether the referent can be perceived by both interlocutors), and *group membership* [3] (whether a speaker and an addressee share knowledge or frame of reference by belonging

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[3] Clark and Murphy (1982) label this *community membership*, which can be considered as a somewhat narrow term. *Group membership* will be used here, since it to a greater extent includes more general psychological features (e.g. age) that are independent of which specific community a listener belongs to.

to the same community or group). In essence, by accessing the common ground through group membership, the speaker does not rely on information regarding the physical or linguistic context of the conversation, but rather on information about the inferred world knowledge or frame of reference of their interlocutor. This information can be obtained by considering factors such as the age, gender or cultural background of the listener.

Taking the common and privileged ground into consideration during online communication is a key aspect of successful reference production (Gillis and Nilsen, 2014). Primarily, studies on AD in reference have examined utterance modification with respect to speaker-listener differences in physical co-presence and linguistic co-presence (Davies et al., 2016; Fukumura, 2016; Grigoroglou and Papafragou, 2019; Horton and Spieler, 2007; Loy et al., 2020; Nadig and Sedivy, 2002; Nadig et al., 2009; Nilsen and Bacso, 2017; Nilsen and Graham, 2009; Saryazdi and Chambers, 2020; Serratrice and De Cat, 2018). However, tasks designed to measure AD by altering the physical (e.g. visual) co-presence of interlocutors have been criticized, since optimal performance in tasks of this kind can be achieved using selective attention alone (Rubio-Fernández, 2017). An example of such a task is the well-established and commonly used Directors task (Keysar et al., 2000). In this task, the speaker directs the addressee to move objects along a grid of squares. The key feature of the Directors task is that some of the objects in the grid are only visible to the participant (who can be either speaker or addressee). Participants who base their interaction (e.g. utterance formulation or eye movement) on objects visible to their confederate while disregarding objects in their own privileged view, have traditionally been understood as sufficient perspective-takers. Evidence at variance with this interpretation comes from Rubio-Fernández (2017), suggesting that participants can employ a strategy of only focusing on objects in white squares (visible to the confederate) and ignore objects in black squares (not visible to the confederate), without actually reasoning about their partner's perspective. This brings in to question such tasks' validity of measuring pragmatic ability. To address this issue, Bentdz et al. (2020) created a task that required participants to take into account the world knowledge (rather than visual perspective) of listeners in order to produce sufficient referential expressions. This paradigm is presented in what follows.

2.1.1 A novel paradigm for modelling common ground on the inferred frame of reference of hearers

According to Clark and Murphy's (1982) group membership heuristic, speakers take into account *who* their listener is during utterance formulation. A novel method of measuring this behaviour was developed by Bentdz et al. (2020). The purpose was to create an AD task that required participants to infer the knowledge state of their interlocutors. In their task, young adults were instructed to verbally direct an addressee to choose a target item, which could either be assumed to be known (known condition) or unknown (unknown condition) to the addressee depending on their age, gender or cultural background. A successful method of denoting the unknown targets was by describing them, in lieu of simply providing their names (e.g. 'The machine with four propellers' vs 'The drone', when directing a 91-year-old female hearer). Results from Bentdz et al. (2020) indicate that adults take into account the identity of the hearer when forming their referential expressions.

Adopting a similar paradigm, Pagmar et al. (2021) found a different behaviour among 7-year old children. Specifically, children chose one of the two strategies (describing vs naming, although tentative results suggest naming was most prevalent in the unknown condition) and continued to use that strategy throughout the task, regardless of condition. This suggests that children do not adapt their utterances to the frame of reference of hearers. However, a major issue

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interpreting the performance of the children in Pagmar et al. (2021) is that while their knowledge of the targets was controlled for, their assumptions regarding the addressees' knowledge of the targets were not. Thus, it cannot be resolved whether the children maintained the same strategy because (1) they consistently inferred that the listener had knowledge of the referent and hence that describing the targets was redundant, or (2) they did not adapt their utterances in accordance with their assumptions of the listener's frame of reference. The former being an example of failed inference regarding listeners' knowledge states, whereas the latter exemplifies an absence of AD-behaviour. These considerations underline the importance of controlling for participants' assumptions regarding their listeners' knowledge in similar paradigms.

Studies investigating AD with respect to differences in interlocutors' frame of reference/world knowledge have either been conducted on children (Pagmar et al., 2021) or adults (Bentdz et al., 2020). Little is known regarding how the ability to use information about others' knowledge states during online production develops in adolescence. The cross-sectional comparison of the two age groups (11-12 and 15-16) in the current experiment moves beyond previous work, by investigating the development of AD in early and middle adolescence.

In summary, AD is the tendency to tailor one's utterance to suit the specific needs of one's interlocutor. It includes adjusting the informativeness of referential expressions in commensurate with listeners' assumed frame of reference – a task that requires the speaker to consider the listener's level of access to the target referent and furthermore create a model for what is common ground (knowledge shared by both interlocutors). If the speaker infers that the listener does not share knowledge about a given referent, she might increase the informativeness of her referential expression to provide the information necessary for successful denotation. Previous studies suggest that factors such as listener age, gender or cultural identity generally affects the informativeness of adults' (Bentdz et al., 2020), but not children's (Pagmar et al., 2021) referential expressions. However, results from children (i.e. Pagmar et al., 2021) are difficult to interpret since their assumptions regarding their interlocutors' frame of reference were not controlled for. Little is known with regards to how AD in reference develops throughout adolescence. In the following sections, the literature on the development of perspective-taking in referential communication is reviewed.

2.2 The development of audience design in referential communication

Piaget (1928/2002) claims that children under the age of 7 virtually 'speak to themselves' (p. 206). By that, he means that children are unable to adapt their utterances in accordance with others' knowledge states. Giving support to this notion, research has found that 5– to 6-year-old children frequently fail to use information regarding their interlocutor's perspective during referential communication tasks (Nadig and Sedivy, 2002). Despite this 'egocentric' behaviour, children as young as 3 years old reason about others' mental states and recognize that these mental states can differ from their own (Perner and Leekam, 1986). This ability is known as *mentalizing* or *Theory of Mind* (ToM) (Astington et al., 1988). Albeit typically developed children over 7 pass most existing ToM tests (Peterson and Wellman, 2019), work on the social cognitive development beyond childhood shows that adolescence represents a period of significant growth in perspective-taking efficacy (Choudhury et al., 2006), and that activation in brain regions involved in assessing common ground (Vanlangendonck et al., 2018) change in adolescence (Blakemore, 2008). The main goal of this section is first to give a brief overview of the development of ToM in childhood and adolescence, and second to account for previous research on the development of perspective-taking during online referential communication.

While views regarding at which age adolescence is reached vary across cultures, most researchers agree that its commencement coincide with the onset of puberty (Blakemore, 2008). The offset of adolescence is less clear. Although there is no widely accepted chronological definition of the sub-stages of adolescence (Curtis, 2015), three phases of transitional youth will be used in this thesis for the purpose of clarity: early adolescence ranges from 11 to 13 years, middle adolescence from 14 to 17 years, and late adolescence/early adulthood reaches from 18 to 24 years (Curtis, 2015).

2.2.1 Theory of Mind in childhood and adolescence

In order to consistently produce perspective-appropriate referential expressions, speakers must be able to assess the informational needs of their interlocutors. This entails recognizing that others' knowledge states can differ from their own. Children exhibit this latter ability from a very young age (Wellman, 1992). For instance, Perner and Leekam (1986) showed that 3- to 4-year-olds were able to keep track of and reproduce specific information that a play-partner had missed due to being out of the room.

ToM is a collection of concepts that allow individuals to perceive others as mental beings driven by their own emotions, perspectives, attentional states, beliefs and desires (Astington et al., 1988, p.3). Despite the lack of consensus regarding the basic characteristics of ToM (Wellman, 1992), many researchers agree that concepts found to comprise the construction are acquired sequentially and consistently in children around the world (Callaghan et al., 2005; Shahaeian et al., 2011; Wellman and Liu, 2004). First, children learn that others have individual beliefs, desires and access to knowledge. Second, they recognize that others can have false beliefs and are able to conceal emotions. In typically developed children, these five concepts are achieved before the age of 6 (Wellman, 1992). However, longitudinal behavioural data reveals that ToM skills continue to develop steadily throughout childhood. For example, in addition to providing support for the sequential acquisition of the five above mentioned concepts, Peterson and Wellman (2019) demonstrated that the ability to understand sarcasm (i.e. that others can mean the opposite of what they are saying) continues to develop in typically developed children between the ages 10 and 11. This suggests that more intricate ToM-processes develop well after the pre-school years, during a time when school children's social world becomes increasingly peer-oriented and complex.

With respect to mentalizing abilities in adolescence, evidence from neuroscience has shown that brain regions key to ToM processes (such as the medial prefrontal cortex and temporo-parietal regions) undergo structural and functional changes during adolescence (Blakemore, 2008). This is especially noteworthy in the scope of the current study, since activation in the medial prefrontal cortex was observed during a referential communication task that involved accessing common ground information (Vanlangendonck et al., 2018). Furthermore, Bentdz et al. (2020) found activation in these areas during online pragmatic comprehension. But how do these changes in the activity and structure of the neural substrates involved in mentalizing processes affect behaviour? Since children entering school age perform well on most ToM tasks (Peterson and Wellman, 2019), designing experimental paradigms that do not generate ceiling effects has been a challenge for behavioural scientist trying to trace the development of ToM beyond childhood (Blakemore, 2008). However, data suggest that individuals become increasingly effective at taking others' (emotional) perspective throughout adolescence, as reflected by shorter reaction times and less variation within age groups (Choudhury et al., 2006). Much like the literature regarding the development of ToM in adolescence, the literature on the development of adolescents' online ToM-usage in communicative contexts is surprisingly scarce. In the

following section, research on the development of ToM-usage in interaction is reviewed.

2.2.2 Usage of Theory of Mind during online referential communication

Compared to adults, children are less effective when it comes to making their referential expressions as informative as required. In a study conducted by Nadig and Sedivy (2002), 5–6-year old children and adults participated in a task designed to test speakers' sensitivity to the visual perspective of their interlocutors. In this task, participants instructed an experimenter to retrieve a target item from a display case. In the common ground condition, modifying adjectives were necessary in order to successfully disambiguate the target from other competing items on display. The results showed that while adults provided unambiguous utterances in 100% of trials, children produced unambiguous descriptions in 75% of them. In a similar study involving 4–5-year old children, only 39% of the referential expressions were unambiguous (Nilsen and Graham, 2009). These studies suggest that AD in reference production develops successively during childhood, and that children reaching school-age have not yet developed into adult-level proficient referential communicators.

While there is considerable evidence that children are unable to fulfill the informational needs of listeners during reference production, less is known regarding how AD in reference develops throughout adolescence. In one study conducted by Fukumura (2016), 11-16 year old participants (Mean: 13) were asked to describe a target picture that was presented together with a competitor picture. The competitor picture only differed from the target in size. In the common ground condition, the size-competitor was visually available to the addressee, and thus the use of disambiguating size-adjectives was necessary to adequately denote the target. In the privileged ground condition, the use of size-adjectives was redundant from the addressee's perspective. The results revealed that adolescents provided disambiguating adjectives nearly as often as adults when necessary, but failed to omit size-adjectives when they were perspective-inappropriate. Although Fukumura (2016) did not investigate the development of AD in adolescence (i.e. how the performance of 11-year-old participants differed from the 16-year old participants'), the results nevertheless indicate that the ability to take into account information concerning the listener's perspective during online production continues to develop in adolescence.

Additional evidence that the use of ToM during online communication develops throughout adolescence comes from comprehension tasks. For example, Dumontheil et al. (2010) demonstrated that early adolescents (11-13 years) did not perform as well as middle adolescents (14-17 years) when interpreting referential expressions that required participants to take the visual perspective of interlocutors into consideration. Moreover, adults' performance was better than the performance of the middle adolescent group, which suggests that the online usage of ToM continues to develop in late adolescence. Whether this successive developmental pattern of communicative perspective-taking in comprehension corresponds to the development in production can still be considered an unresolved issue.

Speculating an informative model for adolescents' AD progress, a fundamental question arises: does the development of AD in reference production exhibit a steady change during adolescence? More specifically, how does AD in reference production compare between early and middle adolescents? Conceivably, the ability to use ToM during online production mirrors the development in comprehension (as reported in Dumontheil et al., 2010), by successively increasing throughout adolescence. Alternatively, advances may taper off in early adolescence, suggesting that online ToM-usage demands distinct processes in production and comprehension. The current study is the first to address this question, using an experimental paradigm that require speakers to take into account the world knowledge, rather than the visual perspective, of hearers

in order to produce sufficient referential expressions.

This section has been concerned with the development of ToM and its usage during online referential communication. When children become of school age, they perform well on most ToM tasks (Peterson and Wellman, 2019), but have not yet fully mastered the ability to use common ground information in order to make their referential expressions as informative as required. This inability becomes apparent in children's tendency to generate ambiguous statements in referential communication tasks (Nadig and Sedivy, 2002). Albeit the literature on AD in the reference production of adolescents is scarce, a composite of results from production and comprehension tasks suggest that the ability to use ToM during online communication develops successively throughout childhood and adolescence, into early adulthood.

Because children show awareness of others' perspectives (Perner and Leekam, 1986), but fail to use this information during conversation (Nadig and Sedivy, 2002), it has been hypothesized that the online usage of ToM relies on domain general cognitive mechanisms (Nilsen and Fecica, 2011). In the next section, this hypothesis is considered.

2.3 The role of cognitive control function in online audience design

The term cognitive control function (CCF) [4] denotes a set of domain general, higher order processes that facilitate flexible and goal-oriented behaviour (Miller and Cohen, 2001). In novel or demanding situations, CCF is imperative to successfully controlling behaviour and thought (Stuss, 1992). The increased efficiency of CCF throughout childhood and adolescence has been interpreted as a manifestation of cognitive and emotional development (Diamond, 2002).

Among the literature on the links between CCF and pragmatic development, research on working memory, inhibition and cognitive flexibility is most prevalent (Matthews et al., 2018). Working memory allows individuals to maintain and update information online (Diamond, 2002), inhibition authorizes the restraint of behavioural and mental impulses (Leon-Carrion et al., 2004), and cognitive flexibility enables the shifting of attention and selection of information (Deák, 2004). In support of the rather intuitive notion that these processes assist in guiding upcoming responses in communicative contexts, a meta-analytic study found a positive correlation between measures of CCF and global measures of pragmatic ability in children (Matthews et al., 2018). The study however concluded that that the relation between CCF and specific pragmatic abilities is still unsettled.

A core question in the referential communication literature is *why* children, and to some extent adolescents, are incapable of effectively adjusting their referential expressions to meet the needs of listeners. This inability is particularly puzzling given that children as young as 3–4 years old are able to understand that others' knowledge states can differ from their own (Perner and Leekam, 1986). One posited theory is that usage of ToM in conversation demands cognitive effort, and that domain general cognitive mechanisms play a crucial role in facilitating mental state attribution during online communication (Nilsen and Fecica, 2011). Because CCF is not yet fully developed in adolescence (Anderson et al., 2001), taking into account the knowledge state of listeners during utterance formulation may require too much cognitive load on individuals without sufficient CCF. In what follows, a theory of a trade-off between AD-behaviour and speaker ease is presented.

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[4]Again, note that CCF is here used interchangeably with executive function.

2.3.1 A trade-off between formulating listener-appropriate expressions and speaker ease

Communicative perspective-taking may seem effortless. Conversely, it is a complex process in which interlocutors are required to manage the flow of linguistic, social and contextual input, while conjointly planning their conversational contributions (Nilsen and Fecica, 2011). An example of speakers' tendency to prioritize ease over AD during utterance formation comes from Brennan and Clark (1996). In the initial trial of their referential communication task, speakers needed to employ a certain level of specificity, since lexemes denoting competing referents were co-hyponyms (e.g. 'birch', 'hazel' and 'willow' are co-hyponyms of the hypernym 'tree'). In subsequent trials, labels of the competing objects did not share semantic fields (e.g. 'tree', 'shoe' and 'car'), and thus, the same level of specificity was redundant. Despite this redundancy, speakers adopting the appropriate level of specificity in the initial trial continued to be specific when more general expressions would have sufficed. This indicates that the eventual pay-off of switching strategies (adjusting the informativeness of referential expressions in adherence to Clark et al.'s (1983) Principle of optimal design), was not worth its processing costs.

During recent decades, a model concerning the trade-off between salience in meaning and speakers' processing efforts in communication has emerged (see, for instance Bacso and Nilsen, 2017; Gillis and Nilsen, 2014; Nilsen and Bacso, 2017; Nilsen and Fecica, 2011; Nilsen et al., 2015). According to this framework, in order to produce listener-appropriate referential expressions, the speaker has to: (1) suppress an 'egocentric' perspective (inhibition) and (2) switch to a listener-friendly perspective (cognitive flexibility), while (3) maintaining and updating information relevant to model common ground (working memory) (Matthews et al., 2018). Pursuant to this model, if the cognitive load of managing the information flow becomes too heavy, the speaker might revert to the 'egocentric' behaviour of producing an utterance that does not suit the informational needs of her interlocutor (Epley et al., 2004). Accounts from meta-analytic studies report that children with ASD or ADHD, which are diagnoses typically associated with diminished pragmatic skills (Loukusa et al., 2018; Staikova et al., 2013), exhibit deficits in CCF (Demetriou et al., 2019; Willcutt et al., 2005). These deficits have furthermore been related to why children with ADHD and ASD do not perform as well as their typically developed peers in referential communication tasks (Dahlgren and Sandberg, 2008; Nilsen et al., 2013).

Evidence from direct measures on the relationship between CCF and the ability to adjust the informativeness of referential expressions is mixed. Nilsen et al. (2015) found a link between measures of 9- and 12-year-olds' CCF (working memory and inhibition) and their tendency to provide unambiguous utterances. However, in a similar study on younger children (years: 4-5), no link between CCF (working memory, inhibition and cognitive flexibility) and the ability to provide sufficiently detailed referential expressions was observed (Nilsen and Graham, 2009). On the adult side, Horton and Spieler (2007) found that young adults (*N*=24) were better at adjusting the informativeness of utterances to suit their conversational partner than elders (*N*=24), which, combined with group-level measures of working memory, led the authors to conclude that the lack of AD in elders' utterances may reflect the difficulty of accessing listener-specific information from memory during online communication [5]. Contrary to this, Bentdz et al. (2020) found no correlation between adults' performance on a referential production task and their working memory capacity. Note that Bentdz et al. (2020) had a considerably larger sample size (*N*=201) than the study that reported correlations.

In attempts to explain the mixed findings regarding the role of CCF in referential communication, researchers have proposed that this role varies across the life span (Matthews et al.,

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[5]It should be noted that the mean working memory scores for the younger adult population were retrieved from another sample (i.e. not participants in the referential communication task).

2018; Nilsen and Graham, 2009). In other words, it is possible that some CCF subfunctions play a central role in communicative perspective-taking during adolescence, but not early childhood. Because Nilsen et al. (2015) found a correlation between measures of 9- to 12-year old participants' CCF and the ability to produce listener-appropriate referential expressions, such a link may be expected among early adolescents in the current study. Whether this link remains in middle adolescence, which is an important period of social and cognitive growth (Blakemore, 2008), has to the best of my knowledge not been tested.

To summarize, CCF is a set of processes vital to guiding thinking and behaviour (Miller and Cohen, 2001). It has been suggested that CCF enables the usage of ToM information during communication (Nilsen and Fecica, 2011). According to this model, speakers may revert to an 'egocentric' behaviour in favour of processing ease, when the demands of managing the information flow in conversation become too heavy (Nilsen and Fecica, 2011). Evidence for a relationship between the ability to produce listener-appropriate referential expressions and CCF is mixed (Matthews et al., 2018), and little is known regarding this relationship in adolescence. In pursuance of contributing to the understanding of online AD's reliance on CCF, and addressing the issue of how this eventual reliance develops across the life span, the current study will examine the link between AD behaviour in reference production and CCF in adolescence.

2.4 Aim and research questions

2.4.1 Aim

The aim of the present study is to trace the development of audience design in reference production during early and middle adolescence (years: 11-12 and 15-16) and investigate its reliance on cognitive control function (CCF).

2.4.2 Research questions

1. Does the ability to adapt utterances to hearers' assumed knowledge states increase as a function of age in early and middle adolescence?

2. Do measures of adolescents' CCF predict their ability to adapt utterances to hearers' assumed knowledge states?

    (a) Do measures of CCF predict the ability to adapt utterances to hearers' assumed knowledge states in early adolescence?

    (b) Do measures of CCF predict the ability to adapt utterances to hearers' assumed knowledge states in middle adolescence?

3 Method

3.1 Participants

The final sample consisted of 59 adolescents from two age groups (11-12 years: $N = 30$, 18 girls; 15-16 years: $N = 29$, 17 girls), recruited from two schools in Värmdö municipality, Stockholm. By disseminating information via the participating schools, parents of children in the younger age group who were willing to allow their child to participate were first recruited. Participants in the older age group were recruited directly via their school. To ensure that participants had Swedish as one of their dominant languages, being a fluent speaker of Swedish at 7 years old was a criteria [6]. Five additional adolescents participated, but were excluded from the analysis due to having been diagnosed with ASD, ADHD and/or DLD (Developmental Language Disorder). Informed consent was obtained from the legal guardian(s) of participants in the younger age group, as well as all participants. Upon participating, the adolescents in the older age group received a gift card to a value of 50 SEK, and the participants in the younger age group were offered confections. The study was approved by the Swedish Ethical Review Authority (Dnr 2020-07083). Information and consent forms provided to participants are available in Appendix A.

3.2 Materials and procedure

During one full half hour session, the participant was presented with two tasks respectively designed to measure (1) audience design (AD) in reference production and (2) cognitive control function (CCF). The AD task was always the first administered, since it was considered the most important task in regards to the research questions. Throughout the experiment, the participant was seated at a table beside an experimenter and in front of a laptop. In the AD task, the participant was recorded using the laptop's built-in microphone. The experiment was conducted in a quiet room at the participant's school.

3.3 Tasks

3.3.1 Test of audience design (AD)

The referential production task used in the present study was adopted from Bentdz et al. (2020) and Pagmar et al. (2021). The aim of the task was to measure adolescents' ability to adapt their referential expressions to the inferred frame of reference of their addressee. Successful reference entailed providing at least one visual feature of a referent, rather than for example using its name (e.g. 'The blue bird' vs 'The Twitter logo'), in cases where the addressee was not assumed to have knowledge of the referent.

In each trial, a picture of the addressee (either a child or an elderly woman) was presented in the upper corner of a laptop screen. At the bottom of the screen, one target (e.g. a video game character, a musician, or other individual/object) and three competitor pictures were displayed. In both of the task's conditions, the speaker knew the name of the target but assumed that the addressee either (1) did not know the name of the target (unknown condition) or (2) did know the name of the target (known condition). An example of four trials from the task's two conditions is given in Figure 1. Participants' knowledge of each target referent and their assumptions

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[6]This criteria was considered a straightforward approach towards ensuring that all participants had equal opportunity to understand the information provided during the course of participation.
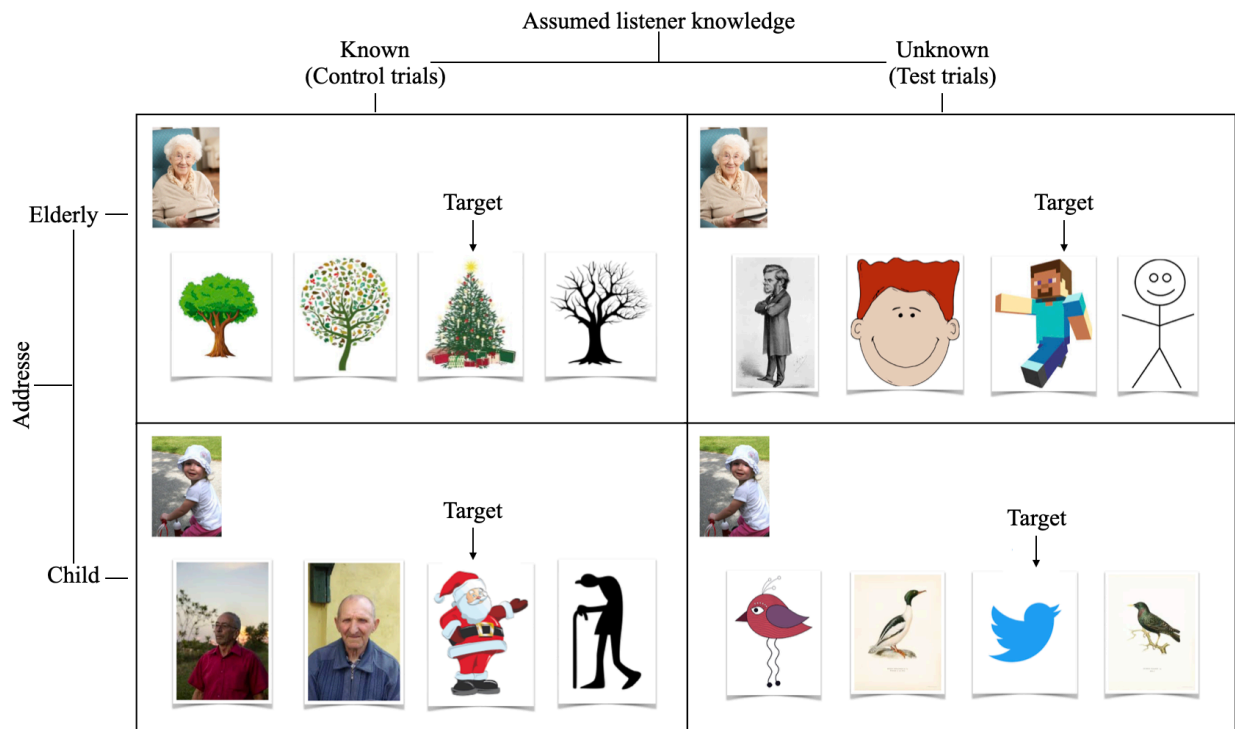
Figure 1: Examples of four trials showing the AD task's two conditions with two addressees. In the exemplified known trials, the targets are a Christmas tree and a Santa Claus. The targets in the unknown conditions are a Minecraft character and the Twitter logo.

regarding the listener's knowledge of each target referent were controlled for through post-test surveys.

During the practice trial, the participant was instructed to say something that would enable their addressee to choose the target picture. The practice trial was always a known condition trial (where both the speaker and addressee knew the name of the referent and thus referring by describing was unnecessary). This choice was based on pilot runs of the experiment, in which only participants that were presented with an initial unknown condition trial described referents throughout the entire experiment, irrespective of trial condition [7]. Interestingly, the AD task from Pagmar et al. (2021) (where a portion of the participating children described referents throughout) had a practice trial that required them to describe the referent in order to succeed. If a participant during the current experiment's practice trial chose to describe the target (again, describing was redundant in the practice trial), for instance, 'the tree with a star', the experimenter always uttered: 'Yes, and you could also just say Christmas tree, right?'. This was deemed necessary in order to avoid the risk of having any participant misunderstand the task, thinking that they were expected to consistently describe the target.

Unlike Bentdz et al. (2020) and Pagmar et al. (2021), stimuli in the current task were selected to suit the frame of reference of adolescents. In as many unknown condition trials as possible, it was vital that the participants would know the name of targets, as well as assume that the listeners did not know the target names. To achieve this, six 11-year-old individuals (that were not part of the experiment) were recruited through their parents to complete an online survey. The parents first received information about the survey through social media posts. The children were presented with pictures of potential targets and asked to (1) provide the names

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[7]The tendency to stick to a single strategy (i.e., either only describe or only use the target name) was not observed in sessions where the initial trial was a known condition trial.

Table 1: Translated examples (from Swedish) of descriptions of target referents. To provide referential expressions that successfully distinguished targets from competitors, a noun phrase (NP) with a maximum of one modifier (an adjectival phrase (AP) or a prepositional phrase (PP)) was necessary.

Target	Competitors	Example of target description
Minecraft character [8]	Cartoon figures (none in t-shirt)	'The man in a t-shirt'
Twitter logo	Pink, white or greenish birds	'The blue bird'
Christmas tree	Trees	'The tree with a star'
Santa Claus	Elderly males without beards	'The man with a beard'

of the referents (by typing the names in a text box) and (2) answer whether they thought that the elderly and child addressees knew the names of the referents. This allowed for deciding which targets might have a higher chance of being known to adolescents in general, as well as which targets were suitable in the unknown condition trials. Furthermore, in an attempt to control for processing efforts of describing targets, the competitor stimuli were chosen so that an NP containing no more than one modifier (e.g. an AP or a PP) was enough to comprise an unambiguous target description. An example of this is given in Table 1. Altogether, the task consisted of 36 trials (24 unknown condition, 12 known condition). Four randomized versions of the experiment were presented in an evenly balanced fashion across participants. The test was implemented using PsychoPy (Peirce, 2007). Since participants varied in number of test and control trials (depending on what they had answered in the post-test survey), the AD-score for each participant was computed as follows:

$$ADscore = \frac{U_{descr}}{U_{tot}} - \frac{K_{descr}}{K_{tot}} \qquad (1)$$

where U_{descr} is the number of successful referential expressions (i.e. descriptions of targets assumed to be unknown to the listener), U_{tot} is the total number of targets that the participant assumed were unknown to the listener, K_{descr} is the number of redundant descriptions (i.e. descriptions of targets assumed to be known to the listener) and K_{tot} is the total number of targets assumed to be known to the listener – resulting in an AD-score somewhere between -1.0 and 1.0. The rationale for subtracting the ratios was to account for the possibility that the participant used describing as an overall strategy (Bentdz et al., 2020).

3.3.2 Test of cognitive control function (CCF)

To assess adolescents' CCF, the Wisconsin card sorting test (WCST) was administered. The WCST is one of the most frequently used neuropsychological measures of CCF (Cummings, 2017). However, the relation between AD and CCF has to the best of my knowledge not previously been analyzed by usage of the WCST. In this task, participants matched cards according to a hidden matching rule (colour, number or shape) that changed after 10 consecutive trials. The task required participants to figure out the rule by trial and error with feedback responses after each matching. WCST performance generally correlate with CCF subfunctions frequently hypothesized to predict AD in reference production (working memory, cognitive flexibility and inhibition) (Lehto, 1996; Steinmetz and Houssemand, 2011; Van Eylen et al., 2011). The performance of children with ADHD and ASD have been shown to exhibit lower WCST performance

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[8]The experimenter learned from the participants that the name of this character is actually 'Steve'.

than that of typically developed children (Tsuchiya et al., 2005). Because children with ADHD and ASD exhibit difficulties in referential communication tasks (Dahlgren and Sandberg, 2008; Nilsen et al., 2013), WCST performance is of particular interest in the current study.

Two WCST scores were utilized: *% perseverative errors* and *% random errors*. A perseverative error occurs when a card is incorrectly matched according to a previous rule although a rule switch has been indicated by the feedback response. A random error (also known as a non-perseverative error) is an error that is not perseverative or efficient (i.e. an error associated with efficient hypothesis testing immediately after a rule change) (Barceló and Knight, 2002). Conceptually, perseverative errors represent difficulty in flexibly switching matching behaviour after a rule change, and random errors reflect difficulty in maintaining successful matching behaviour during a current rule (Barceló and Knight, 2002). Among the three CCF subfunctions mentioned in this thesis (working memory, inhibition and cognitive flexibility), perseverative errors and random errors have both been found to be best predicted by measures of cognitive flexibility and working memory in adolescence (Huizinga et al., 2006; Huizinga and Van der Molen, 2007). Percentage of a given error type was calculated by taking the number of errors of that type divided by 60, which was the total number of experimental WCST trials. The computerized implementation of WCST used in the current investigation was available at PsyToolkit's (Stoet, 2017; Stoet, 2010) experiment library [9].

3.4   Analysis

Most statistical analyses were conducted using univariate generalized linear modelling (GLM). The GLM is an extension of regression models that can be utilized to fit both quantitative and qualitative predictor variables (Haase, 2011, p.24). To test AD as a function of age, AD-scores were analysed with the factor AGE GROUP (11–12 vs. 15–16). In addition, analyses were performed to investigate the relationship between AD and CCF. In these models, the WCST scores (% perseverative errors and % random errors) were independent, continuous variables. All frequentist analyses were conducted with the statistical software R (R Core Team, 2021) and an alpha-level of $\alpha = 0.05$. The model parameters were fit using the built-in functions `glm` (regression with categorical factor and/or continuous predictors), and `aov` (ANOVA with categorical factor).

A Bayesian independent samples t-test with grouping variable AGE GROUP and dependent variable AD-score was conducted in JASP (JASP Team, 2020). Bayesian hypothesis testing is used to assess the relative probability for competing hypotheses (Wagenmakers, 2007). Bayes Factor 10 (BF10) was used to indicate the strength of evidence from the data for H1 (that the two populations' AD-score means are not equal). As an illustration, BF10 = 5 would indicate that there is 5 times more evidence for H1 than H0. Bayesian hypothesis testing is dependent on the hypotheses' prior probabilities (Wagenmakers, 2007). In this study, the default prior in JASP was used, and is described by a probability distribution centred around zero with a width parameter of 0.707.

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[9]https://www.psytoolkit.org/experiment-library/

4 Results

4.1 Preanalysis

Audience design (AD) data from trials with target referents that the post test survey revealed to be unknown to specific participants were excluded from the analysis (133 out of totally 2118 trials). The participants ($N = 2$) from whom most data points were excluded declared that they did not know six of the target referents. A composite of all participants' mean AD-scores was as follows: M = 0.61, std. error = 0.04. A Shapiro-Wilks normality test showed that the AD data was positively skewed (data were normally distributed for the younger age group, whereas 66% of the older adolescents had a score of 0.7 or higher, with the maximum and minimum possible scores being 1.0 and –1.0). Thus, before being fit to the linear regression models, data were transformed using a rank-based inverse normal (RIN) transformation [10], which compared to a wide range of transformation methods have been shown to be most beneficial with respect to statistical power on moderate sample sizes ($N \geq 20$) (Bishara and Hittner, 2012).

4.2 Audience design as a function of age

A univariate generalized linear model with factor AGE GROUP revealed a significant effect on AD performance ($b = 0.84$, std. error = 0.16, $t(57) = 3.68$, $p < .001$). Modelling the non-transformed data generated a similar result [11]. AD performance by age group was: 11–12 years: M = 0.48, std. error = 0.17, 15–16 years: M = 0.74, std. error = 0.17 (Figure 2). The
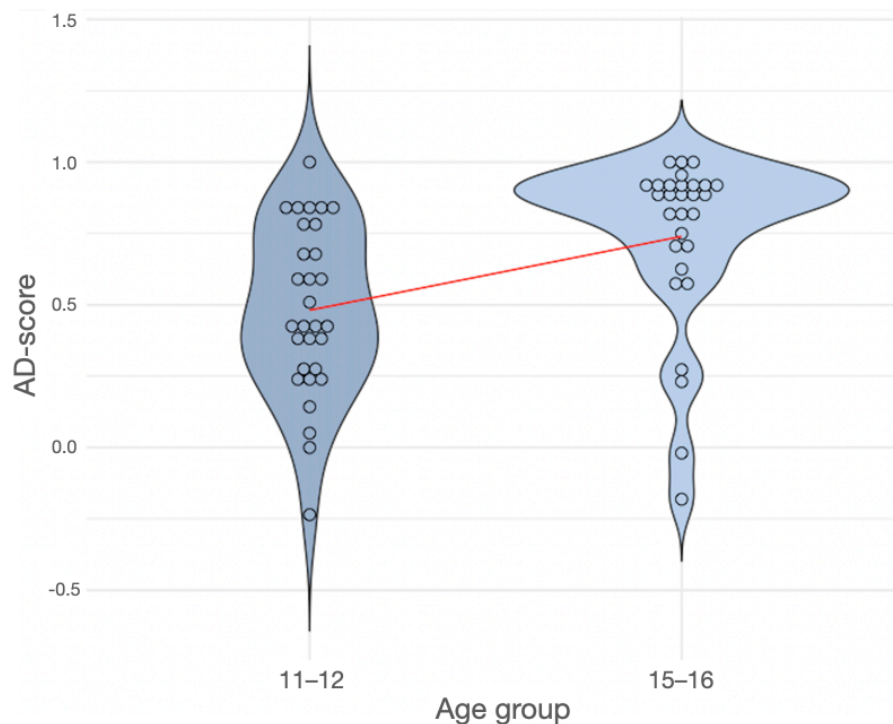
Figure 2: Results from the analysis of age group and AD performance. The red line represents the development of mean ability to adapt utterances in commensurate with the assumed frame of reference of the hearer. The circles represent the performance of individual participants.

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[10] All visualisations of AD performance in this section show non-transformed AD-scores.

[11] Results of AD as a function of age before RIN transformation: $b = 0.26$, std. error = 0.07, $t(57) = 3.32$, $p = .002$).

Bayesian independent samples t-test found strong evidence for a difference in mean AD-score (non-transformed) for the two AGE GROUP levels (BF10: 20.93). Compared to their younger peers, 15-16-year-olds described referents they assumed to be unknown to hearers more often (in 93% vs. 82% of unknown condition trials), and described referents they assumed to be known to hearers less often (in 17% vs. 33% of known condition trials).

4.3 Reliance of audience design on cognitive control function

A univariate generalized linear model with WCST errors as independent variables and both age groups' AD-scores (RIN transformed) as dependant variable did not generate significant effects (intercept: $b = 0.25$, std. error $= 0.37$, $t(56) = 0.68$, $p = .49$, % perseverative errors: $b = -2.01$, std. error $= 2.6$, $t(56) = -0.75$, $p = .45$, and % random errors: $b = -0.47$, std. error $= 2.68$, $t(56) = -0.18$, $p = .86$).

The relationship between measures on CCF and AD performance within the individual age groups was analyzed with two univariate generalized linear models (one per age group). The WCST error scores were independent variables, and the RIN transformed AD-score was the dependent variable in both models. No significant effect of WCST errors on the younger age group's AD performance was observed (intercept: $b = -0.22$, std. error $= 0.58$, $t(27) = -0.38$, $p = .7$, % perseverative errors: $b = -0.57$, std. error $= 3.62$, $t(27) = 0.86$, $p = .88$, and % random errors: $b = 2.83$, std. error $= 3.62$, $t(27) = -0.16$, $p = .4$). No significant effect of WCST errors on the older age group's AD performance was found (intercept: $b = -0.31$, std. error $= 0.59$, $t(26) = -0.53$, $p = .59$, % perseverative errors: $b = 2.03$, std. error $= 3.93$, $t(26) = 0.52$, $p = .61$, and % random errors: $b = 0.37$, std. error $= 6.29$, $t(26) = 0.06$, $p = .95$).

Two follow-up one-way ANOVA tests showed that the amount of WCST errors differed significantly between the age groups. Mean % perseverative errors was lower in the older age group (11-12 years: M = 0.18; std. error = 0.01, and 15-16 years: M = 0.14; std. error = 0.01; $F(1,57) = 13.23$, $p = 0.005$) Mean % random errors was also lower in the older age group (11-12 years: M = 0.12; std. error = 0.01, and 15-16 years: M = 0.07; std. error = 0.01; $F(1,57) = 8.65$, $p < .001$). AD performance and amount of WCST error types per participant are visualized in Figure 3.
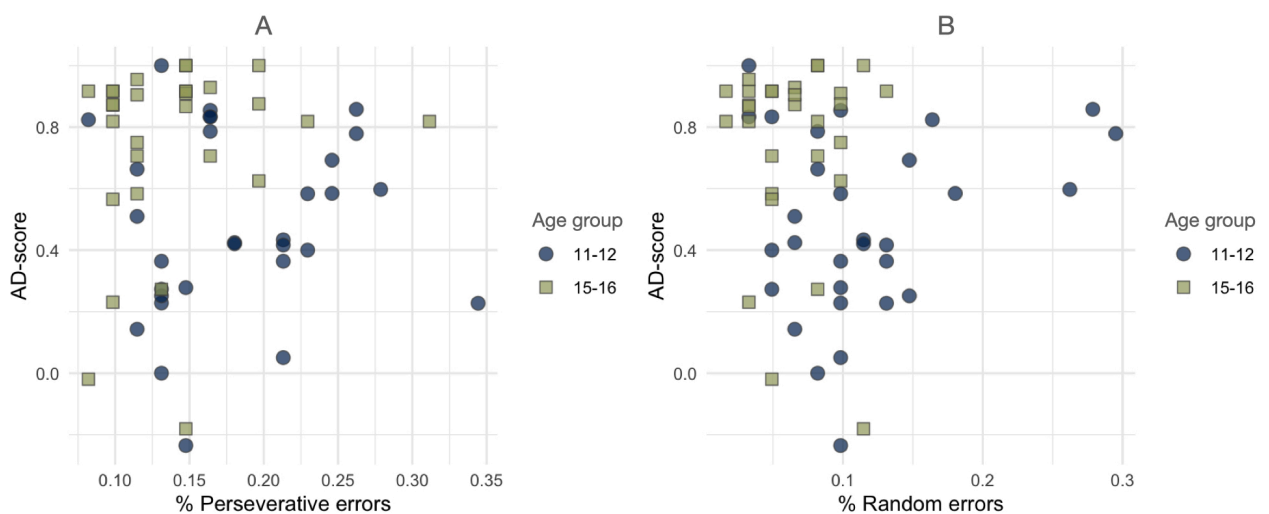

Figure 3: Panel figure showing the relation between AD performance and WCST error types. Visualized in the panels are individual participants' AD-score in relation to % perseverative errors (panel A), and AD-score in relation to % random errors (panel B).

5 Discussion

The goal of the current study was to investigate the development of audience design (AD) in reference production and test its hypothesized reliance on cognitive control function (CCF) in early and middle adolescence. The results show that the ability to adapt utterances to the inferred frame of reference/world knowledge of hearers increases between the ages 11-12 and 15-16. Compared to their younger adolescent peers, middle adolescents more often produce utterances that align with what their interlocutor is judged to know. Considering the theoretical framework of Clark et al. (1983), the results suggest an age-related advancement in adhering to the *Principle of optimal design*; the tendency to base utterance formation on common ground information appears to become more prevalent during the course of early and middle adolescence.

While few studies have examined the development of AD in reference production beyond childhood, the current findings correspond to accounts from comprehension, suggesting a growth in ToM usage during online production between early and middle adolescence (Dumontheil et al., 2010). Previous production tasks have demonstrated that preschool and school-aged children have not yet become adult-level proficient referential communicators (Nadig and Sedivy, 2002). For example, tentative results from Pagmar et al. (2021) suggest that children (age 7) described in less than half of unknown trials [12], as compared with the 11–12-year-olds (82%) and 15–16-year-olds (93%) in the current study. The findings contribute to the field by providing evidence for a successive and late development of the ability to adapt utterances to the inferred knowledge of hearers.

The results also indicate that early and middle adolescents' ability to adapt utterances to the inferred knowledge of hearers cannot be explained by measures of their CCF. This is particularly intriguing, given that the measured WCST performance was higher (fewer errors) in the middle adolescent group. The current results contradict a subset of previous findings in this domain, suggesting a link between domain general cognitive mechanisms and communicative perspective-taking in childhood/early adolescence (for example, working memory and inhibition in 9–12-year-olds in Nilsen et al., 2015). The outcome of this study does however go along the lines of Bentdz et al. (2020), who found no link between AD performance and CCF (working memory) in adults.

In addition to contributing to the understanding of the reliance of AD on CCF across the life span, the absence of evidence for this relationship in the current study puts into question the validity of typical AD-tasks. Firstly, consider that unlike some perspective-taking tasks, such as the well established Directors task (Keysar et al., 2000), the current was designed so that successful performance could not be reached using selective attention alone (Bentdz et al., 2020), but required participants to model common ground by taking into account listener-specific features (e.g. listener age). Secondly, note that counter to Nilsen et al. (2015), the paradigm in the current AD task did not necessitate the retainment of multiple features of competing objects (such as colour, size and/or number) in memory. It has been suggested that referential communication tasks that involve maintaining and updating information on disambiguating features of competing items do put a high demand on cognitive processing (Dahlgren and Sandberg, 2008). Thus, it is possible that many referential communication paradigms require domain general cognitive mechanisms not necessarily crucial to the perspective-taking aspects of the tasks. In order to provide clear data regarding the relation between AD and CCF, future studies should aim to control for cognitive effort in task participation.

However, the uncertainty of which specific CCF subfunctions the WCST actually measures

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[12]As previously mentioned, the children's assumptions regarding their hearers' knowledge of target referents were not controlled for in Pagmar et al. (2021).

obscures the outcome of this study. The WCST has been shown to be an ecologically valid measure of CCF (Kibby et al., 1998), but research suggests that WCST performance taps multiple CCF subfunctions. For example, individual WCST scores do not reflect individual CCF subfunctions (Romine et al., 2004), and the scores used in this study (% perseverative errors and % random errors) have been shown to mainly correlate with working memory and cognitive flexibility in adolescence (Huizinga et al., 2006; Huizinga and Van der Molen, 2007). In consequence, it is possible that some subfunction that was not reflected in the WCST scores, possibly inhibition (although correlating with WCST random errors in 7-year-olds in Huizinga and Van der Molen, 2007), played a role in enabling successful AD performance. In order to avoid ambiguous results, studies should assess CCF through multiple measures that respectively capture its distinct components (Tonér and Nilsson Gerholm, 2020).

This study involved an AD task designed to necessitate ToM-processing. Blakemore (2008) notes that few have conducted such tasks on adolescents, due to risks of producing ceiling effects. Although data from the middle adolescent group was positively skewed, the AD task used in this study did generate notable variance between age groups, suggesting that it is a suitable measure of early and middle adolescents' online ToM usage in language production. This is particularly important, given that the ability to mentalize in communicative contexts have been shown to correlate with adolescents' self-reported well-being (Nilsen and Bacso, 2017). Furthermore, constructing paradigms that sufficiently measure adolescents pragmatic production is crucial to understanding the nature of pragmatic development.

5.1 Possible limitations

Data analyzed in this study come from a controlled experimental environment. Participants were sat in front of a computer and formulated utterances directed at hearers represented by a picture on the computer screen. Similar AD-tasks have been criticized since interactive contexts increase the informativeness of both child and adult speakers' referential expressions (Grigoroglou and Papafragou, 2019). In addition, Grigoroglou and Papafragou (2019) demonstrated that the difference in AD-performance of 4- and 5-year-olds disappeared when they addressed an interactive, rather than a passive, confederate. It is plausible that participants in the current study would have been more motivated to adjust their referential expressions to their hearers if the hearers were active conversational partners, possibly closing the gap between the performances of the two age groups. On the other hand, the difficulty of controlling for the responses of an interactive confederate could have compromised the reliability of the task.

Another possible weakness of the current study is that formal language ability was not controlled for. Many studies investigating formal language (i.e. vocabulary or morphosyntax) as a predictor of pragmatic ability find a medium to strong correlation, although the evidence from referential communication is mixed (for a review, see Matthews et al., 2018). In regards to the AD task, there might be an association between language and referential communication, assuming that more experience in linguistic interaction would generate more frequent learning opportunities as to how to avoid ambiguity of utterances (Matthews et al., 2012), which could culminate to an increased propensity to accommodate the mental states of interlocutors. To a certain degree, the demands on formal language was controlled for in the AD-task, considering that each referent description only needed to consist of a noun phrase with a maximum of one modifier (more specifically, an AP or a PP). With respect to the WCST, while the problem-solving involved in accomplishing WCST has been linked to covert language processes (Baldo et al., 2005), it does not rely on formal language skills as directly as some measures of CCF. Consider for example the Stroop tasks, which generally involve word reading (Williams et al.,

1996). Ultimately, the risk of formal language being the cause of the variance in the data is judged to be minimal.

As mentioned in section 3.3.1, pilot runs of the AD task revealed that using an unknown condition trial (in which describing was necessary to disambiguate the target referents) led participants to consistently describe targets throughout the experiment, regardless of condition. Plausibly, these participants did not understand that naming referents was allowed (and even preferred) in the control condition. This would explain why some of the children in Pagmar et al. (2021) used describing as an overall strategy [13]. Because the current paradigm did use a control (known condition) trial as practice, implicitly suggesting that naming referents was sufficient, it is easier to conclude that adolescents that chose to describe in subsequent unknown condition trials did so because they considered the knowledge state of the listener. For the purpose of collecting reliable data from children, using a control (known condition) trial as practice trial in similar AD tasks is deemed as favourable.

5.2 Ethical considerations

As stated in 3.1, the study was approved by the Swedish Ethical Review Authority (Dnr 2020-07083). All participants were provided with information about the general context of the study and its test procedure. All participants and parents of participants under 15 years old gave informed consent prior to participation. The written consent could not be connected to the registered data. Participants answered background questions regarding any eventual neuropsychiatric or language disorders. Due to ethical considerations of making individuals that showed an interest in the study feel included, all participants that wanted to were allowed to participate, but were excluded from the data analysis if they matched the exclusion criteria (i.e. had been diagnosed with ADHD, ASD or DLD). The rationale for the exclusion criteria was that children with these disorders exhibit difficulties in the abilities investigated in this study (for example Dahlgren and Sandberg, 2008; Demetriou et al., 2019; Rapin, 1996; Willcutt et al., 2005). Information on gender was noted to verify that the age groups were balanced, yielding results that could be generalized across genders. Documents provided to participants are available in Appendix A.

Of great importance was setting up a safe and familiar experimental environment for the participants. This was one of the reasons for conducting the experiment at their schools. Instructions and stimuli in both tasks were adapted to suit the investigated age groups [14]. All participants were informed that they at any time could discontinue the experiment, without having to explain why. The overall impression was that participation was enjoyable and interesting. For most participants, it was their first encounter with scientific research.

5.3 Further inquiries

Previous research has shown that children as young as 3–4 years keep track of others' knowledge states (Perner and Leekam, 1986), but generally do not adapt their utterances to the knowledge of their interlocutor (4–5-year-olds in Nilsen and Graham, 2009, 5–6-year-olds in Nadig and Sedivy, 2002, and 7-year-olds in Pagmar et al., 2021). Thus, it has been hypothesized that some external processes, such as CCF, are necessary to 'prompt' the usage of ToM information in production (Nilsen and Fecica, 2011). The current findings do not provide evidence for this hypothesis in adolescence. Another possibility is that ToM components as such continue to mature

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[13]The practice trial in Pagmar et al.'s (2021) AD task required participants to describe the referent.

[14]The visual stimuli in the AD task were licensed with Creative Commons.

beyond childhood, and that this development causes the increased tendency of the AD behaviour measured in this study. Support for a continuing development of ToM during adolescence can, as stated in section 2.2.1, be found in Choudhury et al. (2006), showing an increased efficiency in taking the emotional perspective of others. Furthermore, Peterson and Wellman (2019) found that the ability to understand sarcasm continues to develop after children turn 10 years old. As a suggestion, the post-test data generated in the current study could be used to determine whether the ability to correctly attribute knowledge states to others develops during adolescence. The original purpose of the post-test survey was inter alia to control for participants' assumptions regarding their hearers' knowledge states. If such investigation would reveal that knowledge state attribution in itself does not develop in adolescence, this would indicate that some other processes are involved in facilitating ToM usage during online production.

Although this investigation is unable to ascertain the underlying cause of the late and successive maturity of perspective-taking in production, its findings conform to neuroimaging research demonstrating that brain areas central to the facilitation of mental state attribution (e.g. lateral temporo-parietal regions and the medial prefrontal cortex) undergo structural and functional changes in adolescence (Blakemore, 2008; Giedd et al., 1999). A goal for future research is to directly measure how changes in the adolescent brain support the development of AD. More specifically, future studies should aim to determine which regions enable the sophistication of common ground modelling and its use during online communication. These types of investigations could not only benefit the treatment of individuals that suffer from difficulties in social interaction, but also lead to a greater understanding of the neurological bases of pragmatic ability.

6 Conclusions

The present study investigated the development of AD in early and middle adolescents' reference production. This was done by comparing 11–12–year–olds' and 15–16–year–olds' performance on a reference production task that required participants to take into account the knowledge state of listeners. Results suggest that the ability to adjust utterances to hearers' assumed knowledge increases considerably between early and mid adolescence.

The study also investigated whether the ability to adapt utterances to hearers' assumed knowledge can be predicted by CCF in (1) early and middle adolescence as a whole, (2) early adolescence, and/or (3) middle adolescence. This eventual reliance was examined by analyzing participants' performance on the WCST task and the referential production task. Although the amount of WCST errors was lower in the older age group, no analysis indicated a link between WCST error types (% perseverative errors and % random errors) and AD-scores. Thus, the current study cannot provide evidence that measures of CCF predict the ability to adapt utterances to hearers' assumed knowledge states in adolescence. Since specific WCST scores do not reflect specific CCF subfunctions, future studies could benefit from investigating the link between successful AD behaviour and CCF in adolescence by using multiple measures that respectively capture distinct aspects of the construct.

A priority for future studies is to determine the underlying processes facilitating the development of online ToM use in communicative contexts. It may be that a development of ToM in itself enables the ability to adapt utterances to the inferred knowledge state of hearers. Typically, children reaching adolescence pass most existing ToM tasks (Peterson and Wellman, 2019), but few ToM tasks have been conducted on adolescents due to risks of ceiling effects (Blakemore, 2008). Existing ToM research do point to a continued development beyond childhood (Choudhury et al., 2006; Peterson and Wellman, 2019), and neuroimaging research indicates that brain regions vital to common ground modelling in referential communication tasks (Vanlangendonck et al., 2018) undergo functional and structural changes in adolescence (Blakemore, 2008). Conceivably, the ability to attribute knowledge states to others becomes increasingly efficient during adolescence. This eventual efficacy may be reflected in the ability to adjust utterances to the inferred knowledge of one's audience.

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A Participant forms – Consent and project description

In this appendix, the documents containing consent forms and information about the experiment are presented. There are three documents, which were respectively provided to parents of participants under 15 years old (A.1), participants under 15 years old (A.2), and participants 15 years or older (A.3). The documents are in Swedish.

A.1 Parents of participants under 15 years

Information till forskningspersonerna
Vi vill fråga dig om du vill att ditt barn deltar i ett forskningsprojekt. I det här dokumentet får du information om projektet och vad det innebär att delta.

Vad är det för projekt och varför vill ni att mitt barn ska delta?
Det har länge forskats mycket om små barns språkutveckling, men vi vet minde om hur ungdomars kommunikation utvecklas. Syftet med projektet är att kartlägga olika kommunikationsstilar hos ungdomar och hur de förändras från att man är 11 till 16 år. Vi frågar dig eftersom du antingen besökt en utställning som bland annat riktar sig mot ungdomar tillsammans med ditt barn, eller att ditt barns lärare varit villig att informera dig om studien. Forskningshuvudman för projektet är Institutionen för lingvistik, Stockholms universitet. Med forskningshuvudman menas den organisation som är ansvarig för studien.

Hur går studien till?
Ditt barn får göra två övningar med hjälp av en dator. Den första är en kommunikationsövning där ditt barn kommer att få se bilder på kända personer/karaktärer och med ord hjälpa en annan person att välja ut en av dem. Den andra övningen är ett minnestest som går ut på att ditt barn ska sortera kort efter färg, form och antal symboler på korten. Det ditt barn säger kommer spelas in. Deltagandet är avidentifierat och tar ungefär 30 minuter. Du svarar också på fyra frågor om ditt barn. Efter experimentet får både du och barnet möjlighet att ställa frågor och berätta hur det var att delta.

Möjliga följder och risker med att delta i studien
Det finns inga risker kopplade till att delta i själva experimentet. Forskningsledarna har erfarenhet av att arbeta med forskningsdeltagare under Coronapandemin och kommer att bära munskydd samt skyddshandskar. Barnet kommer erbjudas munskydd och ytor som deltagarna kommer i kontakt med desinficeras före och efter varje experimentsession.

Vad händer med mina och mitt barns uppgifter?
Deltagandet är avidentifierat och vi kommer inte spara några personuppgifter. Det kommer alltså inte gå att koppla registrerad information till forskningspersonen. De uppgifter vi avidentifierar och sparar är ålder, kön, svaren på bakgrundsfrågorna om ditt barn, samt svaren i de två övningarna. Du och forskningspersonen kommer därför inte att kunna få tillgång till forskningspersonens individuella resultat eller begära att den registrerade informationen raderas. Om ni är nyfikna på studiens resultat som helhet ska ni kontakta den ansvariga för studien (se nedan). Registrerad information kommer att behandlas så att inga obehöriga kan ta del av dem.

Deltagande är frivilligt

Ditt deltagande är frivilligt. Du och/eller ditt barn kan när som helst välja att avbryta deltagandet. Om ni väljer att inte delta eller vill avbryta ditt barns deltagande behöver ni inte uppge varför.

Samtycke till att delta i studien

Jag har fått information om studien och har haft möjlighet att ställa frågor. Jag får behålla den skriftliga infomationen.

☐ Jag samtycker till att mitt barn deltar i studien "Ungdomars kommunikativa utveckling".

☐ Jag samtycker till att uppgifter om mitt barn behandlas på det sätt som beskrivs i experimentinformationen.

Plats och datum	Underskrift

Frågor om forskningspersonen

● Har ditt barn svenska som modersmål (flytande svenska innan 7 års ålder)?

Ja ☐ Nej ☐

● Har ditt barn normal syn- och hörselförmåga (eller normal förmåga med hjälp av hjälpmedel)?

Ja ☐ Nej ☐

● Har ditt barn dyslexidiagnos eller språkstörningsdiagnos?

Ja ☐ Nej ☐

Om ja, ange vilken/vilka:

● Har ditt barn autism/Aspberger-diagnos eller ADHD/ADD-diagnos? Vi vill bara veta om ditt barn har fått en diagnos, inte om det funnits funderingar kring en diagnos.

Ja ☐ Nej ☐

Om ja, ange vilken/vilka:

A.2 Participants under 15 years

Information till forskningspersonerna

Vi vill fråga dig som är 11–12 år om du vill vara med i ett forskningsprojekt. I den här texten kan du läsa om projektet och hur det går till.

Vad innebär det för mig?

Du kommer först att få fylla i din ålder och ditt kön. Sen kommer du få göra två korta övningar med hjälp av en dator. I den första uppgiften kommer du få se flera olika bilder och sen hjälpa en annan person att välja ut en av dem. Det du säger för att hjälpa personen kommer att spelas in. I den andra uppgiften kommer du få sortera kort enligt färg, form eller antal symboler på kortet. Efter experimentet får du möjlighet att ställa frågor och berätta hur det var att delta. Deltagandet är anonymt. Det betyder att du inte behöver säga vad du heter. Innan experimentet kommer du att få fylla i ett papper där du skriver under på att du förstår vad vi har sagt och att du frivilligt vill delta. Du kan när som helst säga att du inte vill vara med längre och du slutar vi med experimentet. Du behöver inte säga varför du vill sluta. När du är klar med experimentet vill vi ge dig vårt tack genom att bjuda på fika.

Samtycke till att delta i studien

Jag har fått information om studien och har fått ställa frågor. Jag får behålla den skriftliga infomationen.

- ☐ Jag vill delta i studien "Ungdomars kommunikativa utveckling".
- ☐ Jag samtycker till att information om mig behandlas så som det beskrivs i experimentin-formationen.

Plats och datum	Underskrift

A.3   Participants 15 years and older

Information till forskningspersonerna

Vi vill fråga dig som är 15–16 år om du vill vara med i ett forskningsprojekt. I det här dokumentet får du information om projektet och om vad det innebär att delta.

Vad är det för projekt och varför vill ni att jag ska delta?

Det har länge forskats mycket om små barns språkutveckling, men vi vet minde om hur ungdomars kommunikation utvecklas. Syftet med projektet är att undersöka olika kommunikationsstilar hos ungdomar. Vi frågar dig eftersom du antingen besökt en utställning som bland annat riktar sig mot ungdomar, eller att din lärare varit villig att informera dig om den här studien. Forskningshuvudman för projektet är Institutionen för lingvistik, Stockholms universitet. Med forskningshuvudman menas den organisation som är ansvarig för studien.

Hur går studien till?

Som deltagare kommer du att få göra två kortare övningar med hjälp av en dator: en kommunikationsövning och ett minnestest. Allt kommer att ta ungefär 30 minuter. Kommunikationsövningen kommer spelas in med mikrofon och går ut på att du ska hjälpa en annan person att peka ut en bild av flera möjliga. Minnestestet går ut på att du ska sortera kort enligt färg, form eller antal symboler på kortet. Efter experimentet får du möjlighet att ställa frågor och berätta hur det var att delta. Deltagandet är anonymt, vilket betyder att det inte kommer gå att koppla dina svar till dig. Innan experimentet kommer du att få fylla i ett så kallat samtyckesformulär där du skriver under på att du har fått tillräcklig information och att du frivilligt vill delta. Du har rätt att när som helst avbryta experimentet utan att tala om varför. När du är klar med experimentet vill vi ge dig ett presentkort på 50 kronor som tack för att du deltog. Möjliga följder och risker med att delta i studien Det finns inga risker kopplade till att delta i själva experimentet. Experimentledaren har erfarenhet av att arbeta med forskningsdeltagare under Coronapandemin och kommer att bära munskydd samt skyddshandskar. Du kommer erbjudas munskydd och ytor som du kommer i kontakt med spritas före och efter varje deltagarsession.

Vad händer med mina uppgifter?

Deltagandet är avidentifierat och vi kommer inte spara några personuppgifter. Det kommer alltså inte gå att koppla registrerad information till dig. De uppgifter vi avidentifierar och sparar är ålder, kön, svaren på bakgrundsfrågorna du svarar på i det här dokumentet, samt svaren i de två övningarna. Du kommer därför inte att kunna få tillgång till dina resultat eller begära att den registrerade informationen raderas. Om du är nyfiken på studiens resultat som helhet ska du kontakta den ansvariga för studien (se nedan). Registrerad information kommer att behandlas så att inga obehöriga kan ta del av dem. Deltagandet är frivilligt Ditt deltagande är frivilligt. Du kan när som helst välja att avbryta deltagandet. Om ni väljer att inte delta eller vill avbryta ditt barns deltagande behöver ni inte uppge varför.

Samtycke till att delta i studien

Jag har fått information om studien och har fått ställa frågor. Jag får behålla den skriftliga infomationen.

☐ Jag vill delta i studien "Ungdomars kommunikativa utveckling".
☐ Jag samtycker till att information om mig behandlas så som det beskrivs i experimentinformationen.

Plats och datum	Underskrift

Frågor om forskningspersonen

● Har du svenska som modersmål (flytande svenska innan 7 års ålder)?

Ja ☐ Nej ☐

● Har du normal syn- och hörselförmåga (eller normal förmåga med hjälp av hjälpmedel)?

Ja ☐ Nej ☐

● Har du dyslexidiagnos eller språkstörningsdiagnos?

Ja ☐ Nej ☐

Om ja, ange vilken/vilka:

● Har du autism/Aspberger-diagnos eller ADHD/ADD-diagnos? Vi vill bara veta om du har fått en diagnos, inte om det funnits funderingar kring en diagnos.

Ja ☐ Nej ☐

Om ja, ange vilken/vilka: