**The frequency, variation, and semantic integration of co-speech
gesture production in verbal adolescents diagnosed with Autism
Spectrum Disorder**

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Abstract

Gestures play an important role in communication, but for populations with atypical language development, gestures are often an area of significant difficulty, especially for individuals with Autism Spectrum Disorder (ASD). Research on younger children with ASD show a significant delay in gesture production, as well as a complete absence of certain types of gestures. However, previous work leaves open the question of whether the frequency and variation of gesture production is impaired also in adolescents with ASD. Moreover, very little is known about the semantic integration of speech and gesture in this population. In the present study, 5 adolescents with ASD and 5 typically-developing adolescents completed a narrative task, in which they were asked to retell a story of 4 animated cartoon clips. The results show that while there is no significant difference between the two groups in the frequency of gesture production and the types of gestures they produce, the frequency of gesture production in the individuals with ASD significantly depends on their verbal working memory skills. Moreover, it seems that many impairments that were confirmed by earlier studies for ASD children in early and late childhood seem to be mere delays that get resolved over time, such as the usage of supplementary gestures.

Key words

gesture, Autism Spectrum Disorder, verbal adolescents with ASD, semantic integration

1 Introduction

Spoken language has been primarily studied and viewed as a unichannel phenomenon, i.e. as a speech or text. However, in the context of personal interaction, speakers make use of different non-linguistic cues that accompany linguistic expression and contribute to the composition of the utterance. These include mostly visual cues such as body movements, facial expressions and gestures (Perniss, 2018). Gestures play a very important role for both communication and cognition, as well as in language development. Research shows that gestures not only precede, but also predict the onset of various linguistic milestones (Goldin-Meadow, 2014). For populations with atypical language development, however, gestures are often an area of significant difficulty, especially for individuals diagnosed with Autism Spectrum Disorder (ASD). In fact, delay in gesture production and the absence of certain types of gestures in the first year of life is one of the first noticeable symptoms of autism (So et al., 2015).

Nevertheless, the majority of the autism research on gesture production is focused on children in their early childhood and there are only few studies focusing on the ability to produce gestures in school-aged children and in adolescents. Specifically, literature on different kinds of gestures is rather sparse and therefore inconclusive. Also, there is a lot of controversy around the frequency of gesture production, since some of the studies do not show any differences between individuals with ASD and their TD peers, while other studies do show a significant difference and argue that the individuals with ASD produce fewer gestures than their TD peers. Moreover, none of the studies on gesture production in adolescents with ASD distinguished between different kinds of gestures based on their semantic integration with speech. All this leads us to our research questions: (1) *Do adolescents with ASD differ in the production of different kinds of gestures when compared to their TD peers?* (2) *Do adolescents with ASD exhibit an impairment in the frequency of gesture production when compared to their TD peers?* (3) *Does the delay in the production of different kinds of gestures based on their semantic integration with speech observed in young children with ASD extend to adolescence? Do they produce different kinds of these gestures when compared to their TD peers?*

In the following section we will introduce some theoretical background regarding our study. In Section 3, we will introduce our methodology, including the description of the participants, the tasks, the procedure of testing, and the way we annotated and analyzed our data. In the Section 4 we will present the findings of our study, which is followed by Section 5 and Section 6, in which we offer discussion of our results and final conclusions, including limitations of our study and suggestions for future research.

2 Theoretical background

2.1 Gestures

Gestures can be easily described as spontaneous body movements we produce in the context of speaking (Kita, Van Gijn, & Van Der Hulst, 1997). Utterances are, therefore, generally seen as constructed out of spoken and gestured material (Kendon, 2004). Due to their complexity and common occurrence, the majority of gesture research, including ours, is focused on hand gestures, even though they can be produced with different articulators, such as head and face (Jakobson, 1972; in Abner, Cooperrider, & Goldin-Meadow, 2015).

Generally, researchers agree that speech and gesture are “two related aspects of the communication system” (Özyürek, 2012: 630). However, there are different views on how the relationship between the two should be explained. On one side, there are functional views (e.g. Clark 1996; Kendon 2004, 2008) according to which gesture and speech are two distinct components that fulfil specific communicative functions when situated in a natural discourse. However, in order to convey the communicator’s message, they have to function together as a “composite multi-modal expression” (Özyürek, 2012: 632). On the other side, there are cognitive theories of gestures (e.g. McNeill, 1992; Kita & Özyürek, 2003), whose focus is primarily on the processing of speech and gesture. These theories see gesture and speech as two representational systems, gesture as imagistic and language as linguistic, that are naturally linked during active language production (Özyürek, 2012).

Either way, gestures are an integral part of language and they do serve different functions in communication. These functions will be discussed in the following subsection.

2.1.1 *Gesture classification*

Based on their function in communication, gestures are generally divided into two main categories: *interactive* and *representational*. Interactive gestures are those that manage the communicative dialogue between interlocutors and the interaction required to maintain the dialogue but they do not convey anything about the content of the speech with which they co-occur (Abner et al., 2015). Face-to-face dialogues are collaborative, and they include an interlocutor who is ready to respond in real-time (Bavelas & Gerwing, 2007). Therefore, in addition to individual processes of language production and comprehension, face-to-face dialogues also require social processes such as coordination and calibration (Bavelas, Chovil, Coates, & Roe, 1995). Coordination and calibration are attained by different means, interactive gestures being one of them. There are plenty of different kinds of interactive gestures that can be observed in face-to-face interactions, for example, gestures for general delivery (e.g. Figure 1), or gestures for giving turn (e.g. Figure 2). However, it is important to point out that there are no standard or stereotypical forms; the form varies from speaker to speaker (Bavelas et al., 1995).

Figure 1: A type of interactive gesture for general delivery.
Speech equivalent: "Here's my point."
(Bavelas et al., 1995: 396)

Figure 2: A type of interactive gesture for giving turn.
Speech equivalent: "You go ahead."
(Bavelas et al., 1995: 396)

Representational gestures, on the other hand, communicate the topic or content of the utterance, and the majority of the research focuses on these (Abner et al., 2005). Across the literature, we can find different classification schemes of these gestures. Here, we will follow the classification introduced by McNeill (1992). McNeill considers gestures to be located on a continuum that he refers to as **Kendon's continuum**, since Adam Kendon was the first one to describe this order in 1983. The continuum includes a wide range of hand movements that can occur during the process of speech. Apart from gestures (also referred to as gesticulations by McNeill), the continuum includes language-like gestures, pantomimes, emblems and signs (Figure 3).

Gesticulations → Language-like gestures → Pantomimes → Emblems → Signs

Figure 3: Kendon's Continuum (McNeill, 1992: 37)

The main criterion that defines the order of these hand movements is the obligatory presence of speech. As we move from left to right, this presence declines and the presence of language properties increases (McNeill, 1992). While gestures (gesticulations) almost never occur in the absence of speech, language-like gestures, though similar in form, usually occur sequentially with speech and are grammatically or lexically incorporated into the utterance. An example could be "the parents were all right, but the kids were [gesture]," where the gesture in the square brackets fills the slot of an adjective. Pantomimes are used to vividly depict objects or actions and the speech is not obligatory (e.g. imitating the action of tooth brushing). Emblems are conventionalized gestures which usually vary across cultures and languages. They are able to convey semantic information without the presence of speech, so they generally stand alone (e.g. the OK sign made by forming a circle with the index finger and the thumb). Finally, signs are parts of sign languages, which are "fully-fledged natural languages with complex grammatical structures which are the major means of communication of many (but not

all) prelingually deaf people” (Pfau, 2012: 513). However, language-like gestures, pantomimes, emblems and signs are categories of hand movements that are not the focus of the present study, and therefore they will not be described in further detail.

Regarding gestures, the focus of our study, McNeill (1992) distinguishes between five main types: iconic, metaphoric, deictic, beat and Butterworth¹. Iconic and metaphoric gestures are both types of *imagistic gestures*, since they depict a certain imagery. While iconic gesture presents an image of a concrete object/event and bears a formal relationship to the semantic content of the speech they co-occur with (1), metaphoric gesture presents an image of an abstract concept, such as knowledge or the topic of the narrative (2) (McNeill, 1992). The speech that co-occurs with a gesture is presented in square brackets and the description of the gesture is written in italics in the line below.

- (1) he tries [going up inside the pipe now]

Iconic: makes an upward movement with his hand

- (2) It was a [Sylvester and Tweety cartoon]

Metaphoric: holds his two hands up, both open, palms facing one another

(Kendon, 2004: 100)

Imagistic gestures are opposed by *non-imagistic gestures* that generally do not depict any imagery. These include deictic gestures and beat gestures. Deictic gestures are “pointing movements which are prototypically performed with the pointing finger”, even though other parts of the body such as head, nose, or chin are often used (McNeill, 1992; 80). Deictic gestures, however, rarely point to a concrete entity but rather choose a region of the speaker’s gesture space to which gesture attaches a referential value (3) (McNeill, 1992). Beat gestures are movements that align with the prosodic and rhythmic structure of the language (Abner et al., 2005). They are “small, low energy, rapid flicks of the fingers or hand,” which can occur even in the rest positions of the hands and “do not present a discernible meaning” (4) (McNeill, 1992; 80).

- (3) and then he [throws] a five-hundred-pound weight

Deictic: points downwards, showing the direction of the weight

- (4) [any time] [she sees him] she [beats] him up

Beats: beat gestures used to highlight important information

(McNeill, 1992: 98-99)

¹ Butterworths, as first described by Brian Butterworth, are simply “gestures that arise in response to speech failures” (McNeill, 1992; 77). They constitute a very small fraction of all gestures, and one of the typical examples could be a “hand grasping or plucking in the air while the speaker is trying to recall a word” (McNeill, 1992). However, these gestures will not be included in our analysis.

	TYPE	DEFINITION	EXAMPLE
Imagistic	Iconic	An imagistic gesture that present an image of a concrete object or event and bears a formal relationship to the semantic content of the speech they co-occur with	Flapping hands to indicate 'bird'
	Metaphoric	An imagistic gesture that present an image of an abstract concept	Clenching the fist in reference to 'pain'
Non-imagistic	Deictic	A pointing gesture used within the speaker's gesture space to which the speaker assigns a referential value	Any pointing gesture occurring in the speaker's gesture space to reference time or place
	Beat	A gesture with no semantic content that integrates with prosodic and rhythmic structure of language	Any up-and-down or back-and-forth movements coinciding with the rhythm of the speech
	Butterworth	A gesture that arises in response to speech failures	Grasping or plucking in the air with hand while trying to recall a word

Table 1: Gesture classification (McNeill, 1992)

2.1.2 Semantic and temporal integration with speech

As we mentioned, utterances are seen as having two components: spoken and gestured, which are co-produced together. This creates a semantic interaction between the two, and gestures are often seen as contributors to the semantic meaning of the utterance (Kendon, 2004). Semantically speaking, gestures can be divided into three main groups: *supplementary*, *disambiguating*, and *reinforcing* (So, Wong, Lui, & Yip, 2014). Semantically supplementary gestures are generally used when providing information that is not fully specified in the speech. It is believed that this is the main semantic function gestures hold (Abner et al., 2015). For example, this could be a child saying '*I eat*' while pointing to a cookie. Disambiguating gestures are used to resolve certain ambiguities in the speech. For example, this could be a child saying '*I like this*' while pointing to a cookie. Reinforcing gestures, also referred to as complementary gestures, are those that reinforce the semantic information already conveyed in the speech. For example, this could be a child saying '*cookie*' while pointing to a cookie.

Moreover, by being co-produced with a linguistic message, gestures and speech create a temporal alignment, which is considered to be a basic property of co-speech gestures and is necessary for the gestures to be actually understood by the listeners that they are delivered to. For example, the iconicity presented in an iconic gesture might be

missed if it is not produced in time alignment with the lexical unit whose meaning it iconically represents (or supplements) (Abner et al., 2015). Moreover, temporal alignment of speech and gestures is also believed to provide prominence to the linguistic unit they accompany (Abner et al., 2015). For example, research shows that the listeners perceive increased prosodic prominence of linguistic units when they are accompanied by a beat gesture, and speakers tend to increase the prosodic prominence of linguistic units when those units are co-produced with a beat gesture (Krahmer & Swerts, 2007).

Up until now we discussed gestures and the role they play in communication. However, in addition to their communicative functions, gestures also play an important role in cognition.

2.1.3 Gestures and cognition

One of the main clues suggesting that gestures play an important role in cognition is the fact that people often gesture in situations in which the interlocutor is absent or cannot see the speaker (Abner et al., 2015). For example, people gesture when they're speaking on the phone (Bavelas, Gerwing, Sutton, & Prevost, 2008; in Abner et al., 2015) or when they are completing a task on the computer (Chu & Kita, 2011; in Abner et al., 2015). Moreover, research shows that also congenitally blind people gesture, even when talking to a person they know is blind, too (Iverson & Goldin-Meadow, 1998). Therefore, it is safe to say that gestures act not only as a communicative but also as a cognitive channel (Abner et al., 2015).

One of the main cognitive functions gestures serve is facilitating lexical access, i.e. helping speakers to retrieve words from the lexical memory. Krauss (1998) suggests that evidence for this specific gesture function can be found in 4 different kinds of data: (i) differences in gesture production during rehearsed and spontaneous speech, (ii) the temporal integration of speech and gesture, (iii) semantic integration of speech and gesture, and (iv) in the effect of preventing people from gesturing during speech production. Indeed, in the study conducted by Rauscher, Krauss, & Chen (1996), 41 undergraduate students had much more difficulty producing fluent speech, especially if the speech contained spatial content, in the condition in which they were prevented from gesturing. Their speech contained much more dysfluencies, specifically filled pauses (i.e. *uh* and *um*), with the majority of them occurring in intraclausal positions. From this finding, we can easily infer that gestures are especially helpful in facilitating the retrieval of spatial information. This was confirmed in a study by Morsella & Krauss (2014), in which 79 university students were asked to describe objects that were visually present or absent. They found that their speakers gestured more when describing objects from memory, i.e. when the objects were not visually accessible. This shows that gestures have a very significant effect on spatial working memory and that they help with the burden that the working memory is presented with.

Very importantly, gestures also play crucial role in language development. Research shows that gestures not only precede, but also predict the onset of various linguistic milestones (Goldin-Meadow, 2014). The discussion of the relationship between co-speech gestures and language development will be covered in the following section.

2.2 Gestures in language development

2.2.1 *Gestures in typical development*

Typically-developing children start using their first gestures around 8-12 months of age. These are typically deictic gestures, used to point to objects to either share interest or to make requests (So et al., 2015). A lot of research shows that the onset of deictic gestures actually predicts the onset of similar spoken words. For example, in their longitudinal study, Iverson and Goldin-Meadow (2005) followed 10 typically developing children from 0;10 to 2;0 years of age and found that the production of a gesture pointing to a particular object (e.g. a car) emerged approximately 3 months before the emergence of the word marking the object, which suggests that the early usage of deictic gestures predicts the usage of the children's first nouns and their first one-word utterances. However, even after they begin to talk, children continue using gestures in combination with words (Iverson & Goldin-Meadow, 2005). The most common type of gestures is reinforcing gestures, also called complementary gestures, e.g. saying 'cookie' while pointing to a cookie, but later on, around 18-24 months of age, they also begin to use gestures for disambiguating and supplementary purposes (So et al., 2015). These gesture-word combinations are a useful technique that helps children to communicate two pieces of information in a single utterance before they are able to produce two-word utterances (Iverson & Goldin-Meadow, 2005). More specifically, we could say that "gestures compensate for the inability to express sentence-like meaning in the spoken modality by offering [...] a tool to express such meaning across modalities" (Özçalışkan & Goldin-Meadow, 2005; in Vandereet et al., 2011). However, more importantly, previous research shows that these gesture-word combinations also predict the emergence of the two-word and, later on, multi-word speech, especially when it comes to supplementary gestures. For example, in a longitudinal study, McEachern & Haynes (2004) observed 10 typically-developing children with a mean age of 15 months and found that none of them produced a two-word utterance prior to producing a supplementary gesture-word combination. The two-word utterances typically appeared 1-3 months after the onset of gesture-word combinations, which occurred between 16-21 months, with a rapid increase at 18 months of age. From this, it is clear that gestures serve an important facilitating function for early language development.

However, the development of gesture production does not end there. Research shows that later on, at the age of pre-school, children are able to produce gestures to clarify a referent that they perceive as ambiguous and they think needs to be specified. For example, in a study by So, Demir, & Goldin-Meadow (2010), the authors tested 12 kids between 2;10 and 5;2 years of age, and found that when children used underspecified forms to refer to referents that needed more specification (i.e. pronoun instead of nouns to refer to new third-person referents), they produced gestures alongside the underspecified forms.

But what does the use of gestures look like in children with atypical development such as children with Autism Spectrum Disorder?

2.2.2 Gestures in Autism Spectrum Disorder

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder that affects the development of brain areas that control social and communication behaviours (Gerenser, 2009). It is a spectrum disorder, which means that “there is a great heterogeneity across behavioural functioning in individuals with autism” (Gerenser, 2009: 71). The typical symptoms include atypical social interaction, perseveration, somatosensory disturbance, atypical communication, mood disturbance, or problems with attention and safety. Based on the severity of these symptoms, we can distinguish between different levels of autism, ranging from higher-functioning individuals to lower-functioning individuals who need substantial support.² However, apart from the heterogeneity in behavioural functioning, there is also a great heterogeneity in language abilities. In general, high-functioning individuals usually develop rather advanced vocabulary and grammatical skills (Gerenser, 2009), while lower-functioning individuals, on the other hand, tend to exhibit severely impaired grammar, with serious cases being completely non-verbal (Tager-Flusberg, 2005).

Gestures, however, have been shown to be an area of significant difficulty for all individuals with ASD (So et al., 2015). In many language-impaired populations, affected individuals tend to compensate for decreased verbal competence by using different means of nonverbal communication, including gestures (de Marchena & Eigsti, 2010). For example, in children with Down Syndrome (e.g. Stefanini, Caselli, & Volterra, 2007) or adults with acquired aphasia (e.g. Buck & Duffy, 1980), gesture rates are much higher than in the typical population. This means that even though the verbal competence in these groups is decreased, communicative intent seems to be intact (de Marchena & Eigsti, 2010). However, when it comes to ASD, the situation looks different. Research shows that individuals with autism exhibit atypical behaviour in both verbal and nonverbal forms of communication. In fact, delay in gesture production and the absence of certain types of gestures in the first year of life is one of the first noticeable symptoms of autism (So et al., 2015). It is a robust finding that young children diagnosed with ASD are particularly impaired in the usage of deictic gestures to point to objects to share interest (e.g. Baron-Cohen, 1989; Carpenter, Pennington, & Rogers, 2002; Wetherby & Prizant, 2002). However, as de Marchena & Eigsti (2010) point out, literature on different kinds of gestures is rather sparse and therefore inconclusive. Moreover, there is a lot of controversy around the frequency of gesture production. Some earlier studies found that children with ASD produce fewer gestures than their typically developing (TD) peers (e.g. Bartak, Rutter, & Cos, 1975), while later studies observed only gesture delays (e.g. Charman, Drew, & Baird, 2003). Some of the studies did not find any group differences and concluded that both ASD and TD individuals produce the same amount of gestures (e.g. Capps, Kehres, & Sigman, 1998). However, regarding semantic integration of speech and gesture, studies show that young children with autism do exhibit an

² For detailed description of these symptoms, see Mayes et al. (2009): Comparison of Scores on the Checklist Autism Spectrum Disorder, Childhood Autism Rating Scale, and Gilliam Asperger’s Scale for Children with Low Functioning Autism, High Functioning Autism, Asperger’s Disorder, ADHD, and Typical Development.

impairment, especially when it comes to supplementary and disambiguating gestures (e.g. Sowden, Perkins, & Clegg, 2008; Sowden, Clegg, & Perkins, 2013).

However, the majority of the autism research on gesture production is focused on children in their early childhood and there are only few studies focusing on the ability to produce gestures in school-aged children and in adolescents. To our knowledge, there has been only one study on gesture production in school-aged children diagnosed with ASD, and it was conducted by So, Wong, Lui, & Yip (2015). According to their results, it seems that delay in quantity of gesture production extends to middle and late childhood (but see the discussion in the previous paragraph). When it comes to the specific types of gestures, the authors found a comparable amount of iconic and deictic gestures, while the amount of emblems was still significantly lower. Regarding the semantic integration, supplementary gestures remained still absent in older children with ASD, while there was no difference in the usage of reinforcing and disambiguating gestures, even though the production of the latter type, as mentioned above, was proved to be impaired in early childhood. It is important to point out that there was still no interaction between the severity of impairment of their language and cognitive functioning and the abundance of gesture production. This means that children with ASD did not produce more gestures to aid their communication, a result consistent with findings from previous studies. Unlike individuals with Down Syndrome or acquired aphasia (as mentioned above), individuals diagnosed with ASD do not use gestures to compensate for their decreased verbal competence. However, the study showed an interaction between the number of gestures produced and the degree of impairment in communication and social functioning. The more severe the symptoms, the fewer gestures were produced.

2.3 Contribution of the present study

In the present study, we are focusing on the production of gestures in adolescents with ASD, which is also still an understudied area. The majority of the studies covering the production of gestures in this group of individuals are mostly focused on their general conversational abilities (e.g. Capps, Kehres, & Sigman, 1998; Capps, Losh, & Thrurber, 2000). The first study that assessed the production of co-speech hand gestures in adolescents with ASD was conducted by de Marchena & Eigsti (2010). In this study, the participants were adolescents with a mean age of 15, and they were asked to complete a narrative task which was prompted with of a series of cards containing black-and-white drawings depicting a story of two monkeys. Participants were expected to observe the cards and retell the story to the experimenter. Inconsistent with findings reported in some earlier studies, both groups (ASD and control) produced the same number of utterances and gestures in their spontaneous production, but the distribution of the gestures was slightly different. While deictic, iconic, metaphoric gestures and emblems were normally distributed, beat gestures seemed to be produced more frequently by the group of TD adolescents. However, this difference was not significant.

In 2014, de Marchena and Eigsti completed another study on gesture production in adolescents with ASD, in which they focused on different contexts in which gestures can be produced. Based on this, the authors distinguished between two main gesture types:

those that serve communicative functions and those that serve cognitive functions. The participants were 19 TD adolescents and 19 adolescents diagnosed with ASD, both groups with a mean age of 15, and they were asked to complete two tasks: a narrative task, eliciting gestures that serve communicative functions, and an executive function task, eliciting gestures that serve more process-oriented functions, e.g. communicating a need. Their results show that adolescents with ASD gesture more often during the executive function task, while their TD peers gestured more frequently while completing the narrative task. This finding suggests that the gestural impairments we observe in individuals with ASD are mostly with those gestures that serve primarily socio-communicative functions. Other gestures that serve more process-oriented functions (e.g. communicating a need) seem to be relatively spared.

While all these studies are an important step towards better understanding of the gestural behaviour in adolescents with ASD, there are still some questions that need to be answered. Specifically, we would like to bring more clarity to the ongoing discussion about the impairment in the frequency of gesture production in individuals with ASD. As mentioned in 2.2.2, there are several studies that do not show any differences between individuals with ASD and their TD peers, while there are also studies that do show a significant difference and argue that the individuals with ASD produce fewer gestures than their TD peers. Moreover, we would like to investigate whether semantic integration of speech and gestures differs in relation to different types of gestures: supplementary, disambiguating, reinforcing. In their study from 2010, de Marchena and Eigsti did investigate semantic integration of speech and gestures, but none of the studies on gesture production in adolescents with ASD distinguished between these types. Studying development of gestures with different semantic functions is of a great importance, since it has been confirmed that in adolescents with ASD, gestures serving social-communicative function are still much more likely to be impaired than those serving cognitive function. These brings us to our research questions:

RQ1: Do adolescents with ASD exhibit an impairment in the frequency of gesture production when compared to their TD peers?

RQ2: Do adolescents with ASD differ in the production of different kinds of gestures when compared to their TD peers?

RQ3: Does the delay in the production of different kinds of gestures based on their semantic integration with speech observed in young children with ASD extend to the adolescence? Do they produce different kinds of these gestures when compared to their TD peers?

3 Methodology

3.1 Participants

For our control group, we tested a total of 5 native English-speaking typically-developing (TD) adolescents aged 12;5 – 15;0 ($M = 14;2$, $SD = 1;8$). They had no history of any developmental disorders and none of them reported any vision or hearing impairments. They are all full-time students at different secondary schools across Cambridge, England, and were recruited with the help of a research associate from the University of Cambridge. For our test group, we recruited 6 native English-speaking adolescents diagnosed with Autism Spectrum Disorder age 12;6 - 16;8 ($M = 14;5$, $SD = 1;7$). One of them, however, refused to finish the task and therefore had to be excluded from the study. Age was matched at the group level (mean age differs of only 4 months between the groups) and at the individual level in 4 participants out of 5 (see Table 2). They were all fully verbal and did not require any substantial support. None of them had any significant hearing or vision impairments. All the participants were recruited from a special needs school in Cambridge, the Castle School. The participants' autism diagnosis, which they had received from clinicians upon the child's acceptance for special education, was confirmed by the head of the school. Prior to the study, we obtained parents' consent forms for both TD and ASD groups.

Participants ASD		Participants TD	
Participant	Chronological age (years;months)	Participant	Chronological age (years;months)
A5 (F)	12;6	T3 (F)	12;5
A3 (M)	13;7	T5 (F)	14;0
A1 (M)	14;3	T4 (M)	14;7
A4 (M)	15;3	T2 (M)	14;11
A2 (M)	16;8	T1 (M)	15;0

Table 2: Individual age matching

3.2 Tasks

The gesture production was assessed through a completion of a narrative elicitation task, for which we used 4 animated cartoon clips as our stimuli. The clips are part of the cartoon *Canary Row*, one of the most commonly used cartoons for gestural research (McNeill, 1992). All the four clips are between 20-40 seconds long, and they depict a cat, Sylvester, who is trying to come up with different ways to catch a bird, Tweety. In Table 3 below, we offer brief descriptions of all the clips used in our study.

Name of the clip	Length	Description
Drainpipe	00:00:34	Tweety is singing in his cage on the window sill, while Sylvester is climbing up the drainpipe to get to Tweety. When Tweety realizes Sylvester is standing next to him, he flies out of the cage into the apartment, followed by Sylvester. The granny gets angry and using an umbrella, she throws Sylvester out of the window.
Bowling ball	00:00:39	Sylvester is trying to reach Tweety's apartment by climbing inside the drainpipe. When Tweety notices it, he grabs a bowling ball and throws it down the pipe. The ball hits Sylvester and ends up in his belly. Now, with the ball in his belly, Sylvester rolls all the way down to the bowling alley.
Catapult	00:00:29	Sylvester builds a catapult that shoots him up towards Tweety's window. As he flies by, he catches Tweety and starts falling down. He falls onto the catapult and starts running away with Tweety in his hands. However, the weight that he used to get to Tweety's window hits his head and Tweety escapes.
Swing	00:00:23	Sylvester is in his apartment drawing a blueprint. When he's finished, he grabs a rope and swings from his window towards Tweety's window. However, the calculations were not accurate and he hit the wall instead.

Table 3: Descriptions of the video stimuli

Prior to completing the main task, all the participants were also asked to complete 2 standardized tests: (1) Coloured Progressive Matrices (CPM) by Raven (1998) and (2) The Children's Test of Nonword Repetition (CNRep) by Gathercole, Willis, Baddeley, & Emslie (1994).

The CNRep task is one of the most used tests of nonword repetition as means of assessing children's language skills. Nonword repetition tests are usually used in the assessment of reading disorders, such as dyslexia. However, they are also used more generally in the assessment of verbal abilities in developmental language disorders (Cilibrasi, Stojanovik, Loucas & Riddell, 2019). This is due to the fact that nonword repetition tasks measure verbal working memory, a cognitive system that provides temporary storage for information available for processing, and the impairment of working memory has been regarded as one of the most important clinical markers of developmental language disorders, including autism (e.g. Bennetto, Pennington & Rogers, 1996; Russell, Jarrold & Henry, 1996). The CNRep consists of 40 made-up words, which are divided into 4 groups based on the number of syllables: 10 two-syllable nonwords, 10 three-syllable nonwords, 10 four-syllable nonwords, and 10 five-syllable

nonwords. The participants were asked to listen to all 40 words, one at a time, and repeat them. The words were recorded by a native English speaker. The answers were recorded on the standard scoresheet designed specifically for the task.

The CPM task is used to measure non-verbal intelligence, specifically abstract reasoning, an important factor of general intelligence (Raven, 1998). The task consists of 3 sets (A, AB, B) of 12 items, making a total of 36 items. The sets are of increasing difficulty, with the first set being the least difficult and the last set being the most difficult. The matrices were presented to the children on a laptop screen, one at a time. They were not given any time limit and could take as long as they needed to find the missing matrix. Again, the answers were recorded on the standard scoresheet designed specifically for the task. For both tasks, CNRep and CPM, we only analysed the raw scores.

3.3 Procedure

The testing took place over the course of one week. The typically-developing controls were tested at their own households, while the participants from our test group were tested at school during school time, in a quiet room, at a time that the class teacher found appropriate. The session had two parts. In the first part of the session, the participants were asked to complete the above-described standardized tasks (CNRep and CPM) presented on a laptop screen. Prior to testing, they received detailed explanations of the tasks and were also presented with practice trials to make sure they understood the procedure of the tasks. In the second part of the session, after they completed the standardized tasks, they were asked to watch the 4 clips, presented to them on a laptop screen. After watching each clip, they were asked to retell the story to the researcher, and these short narratives were videotaped. The whole session lasted between 20-30 minutes and as a thank-you, each participant received a small gift. The participants were not informed about the goal of the study.

3.4 Annotation and analysis

Overall, we obtained 40 videotaped narratives. First, in order to get the overall amounts of words pronounced, we manually transcribed all the narratives. We excluded the words produced by the researcher, as well as speech hesitations, such as filled pauses *uh* and *um*, and unfinished words. After that, all the narratives were annotated in ELAN, an open-source software designed for annotation and analysis of both video and audio data. It was developed by The Language Archive of the Max Planck Institute for Psycholinguistics and it is mostly used for gesture and sign language research. In our annotation, we created 6 tiers. The first tier was used for the speech transcription. The following four tiers were each corresponding to the four types of gestures under investigation: deictic, iconic, metaphoric, and beats (for the description of these gestures, see *Table 1* in 2.1.1). The last tier was used for gesture classification based on the semantic information they convey: supplementary, disambiguating, and reinforcing (see 2.1.2 for the description).

Gestures were classified as *deictic* when the speaker used them to point to an area around him/her, giving it a referential value. Even though the majority of deictic gestures employ the use of the index-finger, there were many gestures that were used to establish a referential value, but employed a different, non-pointing handshape, as in example (5). These were still classified as deictic, as they did not depict any concrete referent (as in iconic gestures) or presented any abstract concept (as in metaphoric gestures).

(5)

Speech: *an [old lady] hits the cat with an umbrella*

Gesture: Here we can see the participant using his entire palm to point to the back, referring the old lady from the clip, who came running from the back of the apartment towards the window sill to throw Sylvester out.

We classified gestures as *iconic* when they visually represented a concrete object or event through specific handshape, motion of the hands or their combination. Also, gestures that resembled deictic gestures because of their handshape but followed an imagined trajectory were classified as iconic, as in example (6):

(6)

Speech: *the cat was [climbing up] the drain*

Gesture: Here, the participant uses his index finger to demonstrate the process of climbing up the drain. Even though the usage of index finger resembles the deictic gestures, he creates a trajectory by moving the finger higher and higher and thus creating an iconicity to *climbing up*.

We classified gestures as *metaphoric* in three different occasions: when they (i) presented any abstract concept, (ii) were used to introduce the topic of the narrative, so-called conduit metaphors, and (iii) presented a transition or transformation within the narrative, i.e. metaphors of change. One of the best examples of metaphoric gestures was produced by the participant A4, which is demonstrated in the example (7):

(7)

Speech: *and [he was finally okay with it]*

Gesture: Here the participant moves both his palms from one side to the other to present a change in the narrative, specifically when Tweety suddenly realizes that he has nothing to worry about because Sylvester's plan is not going to work out.

Gestures were classified as *beats* when the hands of the participants were evidently moving along with the rhythm of their speech. However, if the participant first produced a deictic, iconic, or metaphoric gesture and then kept moving their hands while talking, preserving the handshape of the previous gesture, we did not count these as beats.

Based on the semantic information these gestures conveyed, they were classified as supplementary, disambiguating, and reinforcing. Gestures were classified as *supplementary* when they were used to provide information that seemed not fully specified in the speech (8). *Disambiguating* gestures were those that were used in situations in which the speech allowed for different interpretation, i.e. causing possible ambiguities (9). *Reinforcing* gestures were those that were simply reinforcing the semantic information already fully specified in the speech (10).

(8) And was listening, moving his finger [like this]

Supplementary (iconic): using index finger, the speaker supplements the missing information of how Sylvester moved his finger

(9) And stood on [one side]

Disambiguating (deictic): with his hand, he points to a specific side on which Sylvester stood, as there was an option of other side on which he could have stood

(10) He grabbed [a bowling ball]

Reinforcing (iconic): the speaker uses his hands to create a shape of a bowling ball

In our analysis, we disregarded so-called **adaptors**, touching behaviours or movements that are usually associated with feeling of arousal or anxiety. The majority of them are usually self-oriented, such as scratching, playing with hair or fidgeting with fingers or hands (Anderson, 1999). We also disregarded any subtle hand movements where it was not entirely clear whether they were actual gestures or just a part of continuous adaptive behaviour, as we can see in the example (11):

(11)

Speech: *The bird was safe [inside] his cage*

Hand movement: The fingers of the left hand get slightly extended but then the speaker immediately clasps them around the fist formed by the right hand. Coincidentally, this happens when the speaker is describing the bird being inside his cage, which could be potentially classified as an iconic gesture for *inside the cage*. However, the speaker does not let go of hands and keeps fidgeting with the fingers, which made us classify this as an adaptor.

We also disregarded any vivid and explicit enactment of a person or a situation, which often involved an incorporation of other parts of the body. According to McNeill (1992), these would be classified as pantomimes, a completely separate category from gestures. This was very specific for the participant A5, who often put herself into the role of one of the characters from the videos, as in example (12):

(12)

Speech: *Tweety stopped and [looked]*

Hand movement: Here, the speaker puts herself in the role of Tweety and pretends to be the bird sitting on its swing inside the cage. With her hands, she pretends to hold the handles of the swing the way Tweety did in the video. She also moves her head to look behind her back as if she was Tweety looking back at Sylvester approaching the cage.

4 Results

4.1 Frequency of gesture production

First, we analyzed our data for the overall frequency of gesture production. The participants with ASD produced all together 1507 words and 123 gestures, which is on average 24.6 gestures (SD = 19.5, ranging from 1–54), while the TD controls produced only 1355 words and 108 gestures, which is on average 21.6 gestures (SD = 16.7, ranging from 6–43). From the ASD group, the participant A4 produced the highest amount of gestures, 54, followed by the participant A5, who produced 36 gestures, and by the participant A1, who produced 26 gestures. The participant A2 produced only 6 gestures in total, and one participant, the participant A3, produced only one gesture in all his narratives (Table 4).

	Participant	Words	All gestures	Imagistic		Non-imagistic	
				Iconic	Metaphoric	Deictic	Beat
ASD	A1	322	26	19	1	5	1
	A2	310	6	6	0	0	0
	A3	170	1	1	0	0	0
	A4	418	54	37	6	7	4
	A5	287	36	30	4	2	0
TD	T1	354	41	21	3	14	3
	T2	292	43	26	1	15	1
	T3	195	6	4	0	2	0
	T4	233	8	7	0	1	0
	T5	281	10	8	1	1	0

Table 4: General overview of the gesture production in both groups

With our first model, we aimed to understand whether the amount of gestures produced is significantly different among the two groups. For each participant we first obtained the proportion of gestures by dividing the overall amount of gestures produced by the overall amount of words uttered. Since linear mixed effects models are a reliable statistical analysis even with smaller group samples (e.g. Muth et al., 2016), we checked for the statistical significance of these counts with the following model, where number is our dependent variable and stands for the proportion of gestures:

$$\text{lmer}(\text{Number} \sim \text{Group} + (1|\text{Participant}), \text{data} = \text{table})$$

However, the difference in the frequency of gesture production between the two groups was not statistically significant: $t(8) = 0.018$, $p = 0.986$ ($p > 0.05$)

4.2 Variation between different types of gestures

As a second step, we checked whether there were any differences in the usage of different types of gestures. In both groups, iconic gestures were the most prevalent gesture type, with 93 iconic gestures produced within the ASD group and 66 iconic gestures produced within the TD group. Deictic gestures were the second most prevalent gesture type, with 14 produced within the ASD group and 33 within the TD group. However, two participants from the ASD group, participants A2 and A3, did not produce any deictic gestures in any of their narratives. There were 11 metaphoric gestures produced among the ASD participants, and 5 among the TD participants. The two participants who did not produce any deictic gestures, A2 and A3, also did not produce any metaphoric gestures. There were also two participants from the TD group that did not produce any metaphoric gestures: T3 and T4. The least frequent type was beat gestures, with only 5 gestures produced among the ASD participants and 4 gestures among the TD participants. However, there were only 2 participants in each group who produced beat gestures: participants A1 and A4 from the ASD group and participants T1 and T2 from the TD group.

To investigate these differences further, we used R to create another linear mixed effects model. In this model, group and type are used as predictors (i.e. independent variables) and number, again, is the proportion of gestures (i.e. dependent variable):

`lmer (Number ~ Group * Type + (1|Participant), data = table)`

The results show that iconic gestures were produced significantly more than the other types: $t(8) = 6.386$, $p = 0.000212$ ($p < 0.05$). However, there was no significant interaction between type and group, which means that the effect was observed similarly in both groups. There was also no significant difference in the production of all types of gestures between the groups (Figure 6).

Figure 6: Overall distribution of all 4 types of gestures in both groups

4.3 Interaction with verbal working memory and non-verbal intelligence

Next, we checked whether there was an interaction between the frequency of gesture production and the participants' verbal working memory, as well as their non-verbal intelligence. Table 5 below shows all the raw scores from CNRep task and CPM task for both the ASD and the TD group.

Participants ASD					Participants TD				
Participant	All words	All gestures	CNRep	CPM	Participant	All words	All gestures	CNRep	CPM
A1	322	26	25	24	T1	354	41	38	35
A2	310	6	29	27	T2	292	43	34	36
A3	170	1	26	21	T3	195	6	39	30
A4	418	54	37	34	T4	233	8	38	36
A5	287	36	35	29	T5	281	10	40	35

Table 5: An overview of the raw scores from the standardized tasks

To investigate whether the amount of gestures produced interacts with the participants' verbal working memory skills, we created the following model where group and CNRep scores are used as predictors and number, again, as our dependent variable:

$\text{lmer}(\text{Number} \sim \text{Group} * \text{CNRep} + (1|\text{Participant}), \text{data} = \text{table})$

The results show a significant interaction in the ASD group between the amount of gestures produced and the participants' verbal working memory skills: $t(8) = 2.351$, $p = 0.0466$ ($p < 0.05$). This means that those participants that performed better in the non-word repetition task, i.e. have better verbal working memory skills, also produced higher amounts of gestures (Figure 7). However, while this matters for the ASD group, in the TD group there is no significant relation between working memory skills and number of gestures.

Figure 7: Interaction between the amount of gestures and the CNRep scores in the ASD group

Regarding the non-verbal intelligence, there was no interaction between the amount of gestures produced and the participants' levels of non-verbal intelligence: $t(8) = 0.089$, $p = 0.931$ ($p > 0.05$). To test that we used the following model, where group and CPM scores act as predictors and number as our dependent variable:

$\text{lmer}(\text{Number} \sim \text{Group} * \text{CPM} + (1|\text{Participant}), \text{data} = \text{table})$

4.4 Semantic roles

One of the most significant novel contributions of our study was to disentangle whether there are any differences in the usage of different types of gestures based on their semantic roles. For this, we created a separate data file, and Table 6 shows the amounts of supplementary, disambiguating, and reinforcing gestures produced by the participants from both ASD and TD group.

	Participant	Supplementary	Disambiguating	Reinforcing
ASD	A1	6	0	19
	A2	1	0	5
	A3	0	0	1
	A4	2	3	31
	A5	3	3	25
TD	T1	8	2	25
	T2	12	1	29
	T3	1	0	5
	T4	1	0	7
	T5	0	0	9

Table 6: General overview of the gesture production based on their semantic roles

Reinforcing gestures were the most frequent type of gestures produced among both groups, with 81 produced by the participants from the ASD group, which is 65% of all gestures produced by this group, and 75 produced by the participants from the TD group, which is 69% of all the gestures produced by the TD participants. The second most frequent gesture type was supplementary gestures, with 12 produced in the ASD group and 22 in the TD group. Disambiguating gestures were the least frequent type. Only two participants from the ASD group, A4 and A5, and two participants from the TD group, T1 and T2, produced disambiguating gestures. Once again, we checked for the statistical significance between these differences. for which we used the following model with group and semantic role of the gestures as predictors and proportion of gestures as our dependent variable:

$\text{lmer}(\text{Proportion} \sim \text{Group} * \text{Semanticrole} + (1|\text{Participant}), \text{data} = \text{tablesemantics})$

The results show that reinforcing gestures were produced significantly more often than the other types: $t(8) = 6.196$, $p = 0.000261$ ($p < 0.05$). However, we did not find any significant interaction between this specific semantic role and the group, which means that the effect was observed similarly in both groups. There was also no other significant difference in the production of different types of gestures based on their semantic roles between the two groups (Figure 8).

Figure 8: Overall distribution of all 3 types of gestures based on their semantic roles

4.5 Individual descriptions of the participants

4.5.1 The ASD Group

A1: The narratives produced by the participant A1 were quite elaborate, however, he did not use some of the details that were expected to occur in the narratives, so the researcher asked several follow-up questions. Interestingly, the majority of his gestures were produced while answering the follow-up questions. Moreover, there were few instances of gestures that were produced when he was experiencing problems with finding words. For instance, example (13) demonstrates his very first gesture produced. He was experiencing troubles to find the word *umbrella*, when he was describing the grandma, who took an umbrella to scare Sylvester away:

(13)

Speech: *And then the granny, um, [got, um, (pause)], like, [to throw it away]*

Gesture: Here we can see the speaker clasping his hands to imitate the action of holding an umbrella. However, he produces the gesture while he is experiencing some problems with retrieving the word *umbrella*. This is indicated by the hold of the gesture and some speech hesitations (filled pause *um* and silent pause)

A2: The participant A2 was in his narratives very similar to the participant A1, they even produced a very similar amount of words: 310 for the participant A2 versus 322 for the participant A1. However, interestingly enough, he produced way fewer gestures. To be precise, he produced only 6 gestures in all his narratives, while the participant A1 produced 26. He was also asked a few follow-up questions, but the gesture production did not seem to depend on that.

A3: The participant A3 was not very engaged and produced very brief narratives. He mostly used only 2-3 sentences to describe the events of the story, using no detail. In fact, he produced only 170 words, which is notably less than the previous two participants, and only one gesture in all his narratives. We asked many follow-up questions, however, to those he replied only in one word or a simple phrase.

A4: This participant produced the highest amount of words, specifically 418, and also the highest amount of gestures, 54. His narratives were very elaborate, describing all the events down to every detail, which did not leave much room for follow-up questions. However, even though he produced the highest amount of gestures, many of them were

rather subtle and produced in the proximity of his knees on which he rested his hands. Moreover, he also made a use of some adaptors, especially fidgeting with fingers in between the gestures.

A5: The participant A5 produced 36 gestures, the second highest amount, and similar to the participant A4, her narratives were rather elaborate and detailed. However, in some of the gestures we noticed a lack of temporal integration. Often, they were produced a few seconds later than the speech that they were supposed to accompany. She also used many pantomimes, as we already discussed in the subsection 3.4. She often put herself into the role of one of the characters from the video; however, this was disregarded. There were only few adaptors, such as scratching or touching the hair, but she used them very sporadically.

4.5.2 The TD Group

T1 and T2: These two participants were very similar in the amount of words they produced and also in the amount of gestures they produced. In fact, both of them produced the highest amounts of gestures among all the TD participants (T1 produced 41 and T2 produced 43). Their narratives were elaborate and detailed and there was no need for too many follow-up questions. However, in both participants, the gestures were rather subtle and produced in between various adaptors, mostly fidgeting with fingers.

T3: The participant T3 produced the least amount of words, specifically 195, and only 6 gestures, which was the lowest amount of gestures produced among the TD group. Her narratives were brief, using only few sentences to describe the events of the stories and no detail. This required many follow-up questions, however, she was not very responsive to them and answered only very briefly with a single word or a simple phrase. She was also constantly playing with fingers and because her gestures were also rather subtle, it was sometimes difficult to distinguish between adaptors and real gestures.

T4: The participant T4 was very similar to the previous participant, T3. He produced only 8 gestures and rather brief narratives. He did use a bit more detail to describe the events of the stories, but there was a lot of room for follow-up questions, to which he also responded only very briefly. He was using many adaptors, the most obvious one being touching his face.

T5: The participant T5 produced similar narratives to those produced by the participants T1 and T2 and as in those cases, there was no need for too many follow-up questions. However, she produced only 10 gestures and this contrast is mostly notable when compared to the participant T2, who produced a very similar amount of words (292 for the participant T2 and 281 for the participant T5), but produced in total 43 gestures. Similarly to the rest of the participants in this group, her gestures were rather subtle and was also making a use of different adaptors, mostly fidgeting with fingers, which sometimes made it difficult to distinguish between adaptors and real gestures.

5 Discussion

The primary focus of our research was to bring more clarity into the ongoing discussion about the impairments and delays in gesture production in verbal high-functioning adolescents diagnosed with ASD. First, we checked for the overall frequency of gesture production, which we did by comparing the proportions of gestures that we obtained for both groups. The proportions were obtained by dividing overall amount of gestures to the overall amount of words uttered. The difference between the proportions turned out to be statistically not significant, which means that both groups seem to produce comparable amounts of gestures. This result is in line with some earlier studies that did not find any difference in the gesture production between the adolescents with ASD and their TD peers (e.g. Capps, Kehres, & Sigman, 1998), and also with latest study by de Marchena & Eigsti (2010), who also studied adolescents with ASD between 12-17 years of age and found no significant difference in the amount of gestures produced when compared to their TD peers. This could also be an indication of resolved gestural delays, which have been observed in younger children with ASD in other studies (e.g. Charman, Drew, & Baird, 2003). However, there was a great deal of heterogeneity among our participants in both TD and ASD groups, as we already discussed in subsection 4.5. Specifically, some of our participants were much more eloquent than others and also described the events of the stories in much more detail. Regarding our ASD group, those participants were also the ones that produced the highest amounts of gestures and scored the highest scores in the non-word repetition task, specifically the participants A4 and A5. On the other hand, participants such as A2 and A3, who produced between 1-6 gestures in all their narratives, scored the lowest scores in the non-word repetition task. These results are in line with previous findings which suggest that those individuals with ASD who have more severe impairments in verbal or communication skills are also less able to use gestures (So et al., 2015). Moreover, this could also be another piece of evidence for inability of the individuals with ASD to use gestures to aid their communication (e.g. Luyster, Lopez, & Lord, 2007).

As we mentioned, heterogeneity was also observed in our TD participants. While two of our participants produced above 40 gestures, the rest of our TD participants produced only between 6-10 gestures. Despite the fact that there was no significant interaction between the amount of gestures produced and the TD participants' verbal working memory skills, we did notice that those participants who gestured more did actually score lower in CNRep. For example, the participant T5 scored 40 out of 40 in the CNRep task, but produced only 10 gestures in all his narratives. On the other hands, the participant T2 produced above 40 gestures, but scored only 34 out of 40 in the CNRep task. This pattern suggests that in TD development, individuals do rely on gestures to aid the communication, and in those TD individuals who have poorer verbal skills, gestures are produced much more frequently to lower the cognitive load (So et al., 2015).

Next, we investigated the usage of different types of gestures: iconic, metaphoric, deictic, and beat. Our results show that both groups used iconic gestures significantly more than the other types. However, the participants from our ASD group produced more iconic gestures than our TD participants, even though the difference was not significant.

On the other hand, deictic gestures were used more by our TD participants, but this difference was not significant either. In fact, the differences between the groups were not significant for any gesture type. This finding suggests that the preferences and the counts of different types of gestures are comparable between the groups. Previous research on younger children with ASD shows that they are mostly impaired in the usage of deictic gestures. Even though our TD participants did produce more deictic gestures than our ASD participants (33 by the TD group and 14 by the ASD group), this difference was not significant. Moreover, the impairment in the usage of deictic gestures has been shown to lie primarily in the usage of deictic gestures to share interest, while deictic gestures used to reference time or place are rather spared in this population (e.g. Baron-Cohen, 1989).

One of the biggest contributions of our study was the investigation of different types of gestures based on their semantic roles: supplementary, reinforcing, and disambiguating. The previous research on adolescents with ASD did account for the semantic integration of speech and gesture in general, but did not investigate the usage of different semantic roles of gestures. However, there are studies on younger children with ASD that did investigate these types (e.g. Sowden et al., 2013). The only study that investigated these types in school-aged Cantonese-speaking children with ASD was conducted by So et al. (2015). The research on TD children suggests that reinforcing gestures are the first to develop and are used the most. Indeed, reinforcing gestures are those that were used significantly more than the other types of gestures in both our groups. However, the difference in their use was not significant between the groups, suggesting that adolescents with both TD and ASD have a good grasp of reinforcing gestures. In fact, there was no significant difference between the groups in the use of supplementary and disambiguating gestures either, even though the absence of supplementary gestures was reported in some of the studies on younger children with ASD (e.g. Sowden et al., 2013) and also in the study by So and colleagues on school-aged children with ASD. So et al. (2015) suggest that the absence of supplementary gestures starts in early childhood and persists into the late childhood. However, the participants from our ASD group did produce supplementary gestures alongside the other types. Although they did produce significantly lower amounts of supplementary gestures than reinforcing gestures, they did not produce significantly less supplementary gestures than their TD peers. We take this to suggest that the absence observed in the above-mentioned studies is a mere delay that gets eventually resolved in adolescence.

6 Conclusion and future research

Our findings suggest that both ASD and TD adolescents produce comparable amounts of gestures. This is in line with some of the earlier studies that did not find any differences either. It could also mean that if there ever was an impairment in gesture production, it was a mere delay that eventually gets resolved in adolescence. Regarding the production of different types of gestures, both groups produced significantly more iconic gestures than the other types. However, there were no differences between the groups in the usage of different type of gestures. The same effect was observed with different types of gestures based on their semantic roles. Both groups produced significantly more reinforcing gestures than the other types, but there were no significant differences between the groups. Previous research on children with ASD in their early and late childhood suggest that these individuals are impaired in the usage of supplementary gestures, however, we did not find any significant difference between our ASD participants and their TD peers. This might suggest that the impairment is in fact a delay which is resolved in the adolescence. Nevertheless, in the ASD populations, we found that the frequency of gesture production depends on the level of verbal working memory skills. Those that had higher scores in our non-word repetition task testing their verbal working memory, also produced more gestures.

Even though our study already shows very interesting results and patterns, we did notice some limitations that future research should account for to get more conclusive evidence. For example, for some of them we asked more follow-up questions and for some we asked only a few. Even though this was driven by the fact that some of the participants were immediately very eloquent and detailed in their descriptions and did not leave any room for the follow-up questions, in future research, this could be accounted for and see whether there are differences in monologues and one-to-one conversations. As we already mentioned, there was one specific participant who produced the majority of the gestures while answering the follow-up question but did not produce many gestures in his own narratives. This could be seen as a suggestion that gestural behaviour might differ when interacting with others, since our communicative intentions change and often get influenced by the interlocutor we interact with. Moreover, future studies could also use standardized tasks prior to the actual testing as a means of selecting the participants to lower the heterogeneity and get a clearer picture of the role verbal working memory skills play in the production of gestures. Though we did get a significant effect even with such a small sample, bigger samples and more elaborate group divisions could bring much stronger conclusions.

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