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Listener- Versus Speaker-Oriented Disfluencies in Autistic Adults: Insights From Wearable Eye-Tracking and Skin Conductance Within a Live Face-to-Face Paradigm

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ABSTRACT

Purpose: Our study addresses three main questions: (a) Do autistics and neurotypicals produce different patterns of disfluencies, depending on the experimenter's direct versus averted gaze? (b) Are these patterns correlated to gender, skin conductance responses, fixations on the experimenter's face, alexithymia, or social anxiety scores? Lastly, (c) can eye-tracking and electrodermal activity data be used in distinguishing listener- versus speaker-oriented disfluencies?
Method: Within a live face-to-face paradigm combining a wearable eye-tracker with electrodermal activity sensors, 80 adults (40 autistics, 40 neurotypicals) defined words in front of an experimenter who was either staring at their eyes (direct gaze condition) or looking elsewhere (averted gaze condition).
Results: Autistics produce less listener-oriented (*uh*, *um*) and more speaker-oriented (prolongations, breath) disfluencies than neurotypicals. In both groups, men produce less *um* than women. Both autistics' and neurotypicals' speech are influenced by whether their interlocutor systematically looks at them in the eyes or not, but their reactions go in opposite directions. Disfluencies seem to primarily be linguistic phenomena as experienced stress, social attention, alexithymia, and social anxiety scores do not influence any of the reported results. Finally, eye-tracking and electrodermal activity data suggest that laughter could be a listener-oriented disfluency.
Conclusions: This article studies disfluencies in a fine-grained way in autistic and neurotypical adults while controlling for social attention, experienced stress, and experimental condition (direct vs. averted gaze). It adds to current literature by (a) enlightening our knowledge of speech in autism, (b) opening new perspectives on disfluency patterns as important signals in social interaction, (c) addressing theoretical issues on the dichotomy between listener- and speaker-oriented disfluencies, and (d) considering understudied phenomena as potential disfluencies (e.g., laughter, breath).
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Following the preferences expressed by our participants diagnosed with autism (consistent with the French-speaking autism community preferences; Geelhand et al., 2023), we use identity-first language and refer to them as *autistics* and *autistic adults*. Congruently, people without a developmental diagnosis (e.g., autism, bipolarity, Down syndrome) would be referred to as *neurotypicals* and *neurotypical adults*. A *disfluency* is to be understood here as anything that accidentally interrupts a fluid sequence of words that follows grammatical rules (thus, any intentional interruption or rhetorical effect is excluded). In this article, *disfluency* is a neutral way of describing discourse habits and characteristics rather than an axiological judgment of alleged transgressions, failures, or defaults. We also use *women* and *men* to refer to gender, understood as a social construct (World Health Organization, 2021); note

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that in this study, only one autistic participant had no overlap between her gender and her assigned sex at birth.

Introduction

Disfluencies are thought to influence how the delivered message is received, as well as the way the hearer perceives the speaker (Bosker et al., 2019; Loy et al., 2017). An atypical pattern of disfluencies in the speech of autistic speakers could therefore put them at risk of being misunderstood and misperceived by listeners; recent studies have already evidenced that neurotypicals are likely to form negative first impressions of autistics (e.g., Lim et al., 2021; Sasson et al., 2017), inter alia based on linguistic features (e.g., Geelhand et al., 2021). Disfluencies may deepen the gap between expectations and performance in both neurotypicals and autistics, potentially leading to further disjuncture in reciprocity (Milton et al., 2021), or even mental health issues in autistics (Cage et al., 2018). Studying disfluency patterns in autism might help us understand and support effective social interaction.

Disfluencies are usually divided into two types: *speaker-oriented* disfluencies that reflect cognitive overload and planning difficulties versus *listener-oriented* disfluencies that are geared toward improving communication efficiency, such as negotiating the floor (viz. the speaking role), requesting help, signaling a delay to the interlocutor, or increasing attention (for a review in autistic individuals, see Engelhardt, 2021). It is possible that speech sequences produced by autistics sound different because they exhibit less listener-oriented (i.e., being less helpful to the listener) or more speaker-oriented (i.e., being more complicated to follow) disfluencies. It must be noted, however, that the classification between listener- and speaker-oriented disfluencies adopted below is preliminary and probably tenuous (i.e., a disfluency could be classified in the two categories, depending on its position in a sentence, its linguistic characteristics, its role in the conversation, or even its social context; e.g., Kosmala & Crible, 2021).

Listener-Oriented Disfluencies

Studies of disfluency in autism mostly focused on "fillers," also called "filled pauses." This category combines "hesitation markers" (e.g., *uh*, *um*) and "discourse markers" (e.g., *well*, *so*, *you know*) and even "clicks"[1] (Pinto & Vigil, 2020; Trouvain & Malisz, 2016). Because they are thought to be structuring and helpful to the addressee (giving cues for interpretation), discourse markers can be classified as listener-oriented disfluencies (e.g., Maschler & Schiffrin, 2015). Even though there is still debate on this issue (Kosmala & Crible, 2021), *uh* and *um* are usually considered as words, as they seem to follow semantical, phonological, and syntactic rules (Clark & Tree, 2002) and have identifiable and stable communicative meanings (Kidd et al., 2011; Morin-Lessard & Byers-Heinlein, 2019). Their occurrence is also known to depend on register, context, gender, and socioeconomic status (Tottie, 2011, 2014). Fillers in general, and *uh* and *um* in particular, are usually classified as listener-oriented disfluencies as they convey information to the interlocutor (Barr, 2003; Bortfeld et al., 2001; Bosker et al., 2019), such as signaling an upcoming delay (or embodying it; Schegloff, 2010), keeping the floor, asking for help (Clark & Tree, 2002), signaling novelty (Arnold et al., 2004; Morin-Lessard & Byers-Heinlein, 2019; Orena & White, 2015; Owens & Graham, 2016) and correction (Brennan & Schober, 2001; Ferreira et al., 2004), attracting attention (Fraundorf & Watson, 2011; Staley & Jucker, 2021), or structuring the speech (Tottie, 2014). They also tend to occur more often in conversations than in monologues (e.g., Bogdanova-Beglarian et al., 2020). Previous studies (Lake et al., 2011; MacFarlane et al., 2017; Wiklund & Laakso, 2021) found lower rates of fillers in autistic individuals in comparison to neurotypicals (but see Geelhand et al., 2020) and, more particularly, lower rates of *um* (Gorman et al., 2016; Heeman et al., 2010; Irvine et al., 2016; McGregor & Hadden, 2018) and a lower *um–uh* ratio (Parish-Morris et al., 2017). Some researchers suggested that atypical production of *um* could be a clinical marker of autism specific to men, as autistic women do not seem to differ from neurotypicals in producing *um* (McGregor & Hadden, 2018; Parish-Morris et al., 2017).

"Prolongations" ("stretching out of speech segments"; Eklund, 2001), also called "lengthening" (e.g., *It's* ***a–*** *fruit*), could be included within listener-oriented disfluencies because they can be thought of as fillers (Wiklund & Laakso, 2021). On par with *uh*, prolongations signal or embody a delay and allow the speaker to keep the conversational floor while planning speech. Several articles addressed final sound prolongations in autism (sometimes under other labels, such as "atypical disfluencies" or "dysrhythmic phonations"). Some have found as many prolongations in autistics as in neurotypicals (e.g., Wiklund & Laakso, 2021); others have reported more prolongations in autistics (e.g., Scott et al., 2014). However, it is not clear whether all the researchers actually describe the same phenomena; some consider

[1]Speech sounds are usually consonants articulated with two points of contact in the mouth. In a few languages of the world (mainly in the Khoisan family), they have a phonological status, but they are mostly used as interjections with a wide range of possible meanings, from disapproval (e.g., the dental "tsk-tsk" in English) to difficulties in word retrieval we focus on here.

prolongations to be *disfluencies* that occur in nonclinical samples (e.g., Wiklund & Laakso, 2021, as in this study), whereas for others, prolongations are collapsed with word-final *dysfluencies* (along with final-word repetitions, e.g., *train-ain*) and similar to fluency disorders (Healey et al., 2015; Plexico et al., 2010; Scott, 2015; Scott et al., 2014). In this study, only nonpathological prolongations have been produced.

"Metalinguistic comments," which comprise "self-addressed questions" (e.g., *How does one say that?*), are especially relevant when they concern disfluency production (e.g., *I've forgotten the word*; *It's on the tip of my tongue*; *Sorry*). Metalinguistic comments on disfluencies are likely to serve a listener-oriented function; like fillers, they signal a delay, but in addition, they allow more speech planning time while making explicit the reflection on what has been or what is to be said, thus potentially allowing the addressee to provide help. To our knowledge, metalinguistic comments in autism are understudied, and our study is exploratory in this respect. Self-addressed questions on disfluencies in oral corpora have not been extensively studied, but their meaning seems to be culture dependent (Eckardt & Csipak, 2021; Ginzburg et al., 2013; Tian et al., 2017); in Chinese and English, they seem to mainly signal word-retrieval issues (e.g., *What/Where/Who was it?*), whereas in Japanese, they seem to focus on phrasing appropriateness (e.g., *How to say it?*). No data are available on metalinguistic comments and self-addressed questions in autism (Engelhardt, 2021). In this article, we will investigate the two main hesitation markers separately (*uh* and *um*), along with discourse markers (clicks included), prolongations, and metalinguistic comments (self-addressed questions included).

Speaker-Oriented Disfluencies

Some studies have focused on "repetitions" (e.g., *In a **a** fast way*) in autism, but with somewhat unclear results. Repetitions have been reported more present in autistic than neurotypical speech (Lake et al., 2011; Shriberg et al., 2001; Suh et al., 2014), but this difference in rate is probably (at least partly) due to disparities in verbal abilities (Engelhardt, 2021), as other studies found a negative correlation between verbal IQ and repetition rates (Engelhardt et al., 2013, 2017, 2018). Based on this link between cognitive abilities and repetitions, Engelhardt (2021) suggests that repetitions are speaker-oriented disfluencies, and studies in non-autistics also tended to show that repetitions reflect cognitive effort in front of complex tasks (Bortfeld et al., 2001). However, other researchers argue that repetitions could be (at least) not detrimental to the addressee (Tree, 1995); that they could be used as fillers (e.g., Crible & Pascual, 2020) to maintain fluency despite difficulties (Penttilä et al., 2021); and, in sum, that they would be listener rather than speaker oriented.

"Repairs" are usually defined as deletions or cutoffs of lexical, phonological, or syntactical material that has been uttered and its reparation with new material, often more appropriate or more correct. This category encompasses "false starts" (e.g., ***Whales are mammals that**/There are many whales in the Pacific Ocean*), "self-corrections"/"'revisions"/"substitutions" (e.g., *It's someone/It's **a nursing auxiliary***), "deletions" (e.g., *A bee is an **animal**/an insect*), and "insertions" (e.g., *It's a fruit, it's an **exotic** fruit*). Repairs are considered speaker-oriented disfluencies because they are reported to be more frequent in complex tasks (Bortfeld et al., 2001), to have a rather detrimental effect on comprehension (e.g., Corley, 2010; Ferreira et al., 2004; Tree, 1995), and to be linked to inhibition abilities (Engelhardt et al., 2010). Repairs have been found to be produced more often (but see Lake et al., 2011) by autistics than by neurotypicals (de Marchena & Eigsti, 2016; Engelhardt et al., 2017; Shriberg et al., 2001; Sisskin, 2006; Suh et al., 2014). It also seems that non-autistic men produce more false starts than non-autistic women (e.g., Cohen, 2008). In this article, we will study repetitions, false starts and repairs (collapsing self-corrections, deletions, and insertions, as these are complementary ways of correcting oneself).

Potential Disfluencies

Breaths understood as a disfluency category, comprise exhalations or inspirations that are not driven by physiological needs, such as loud deep-voiced inspirations and expirations, as well as sighs (note that normal breath might have positive roles in conversation management and recollection; Elmers et al., 2021; Rochet-Capellan & Fuchs, 2014). *Sighs* are defined as being a 2–5 times the volume of a normal breath and primarily serve a critical role for ensuring lung functioning (Li & Yackle, 2017). Yet, sighs have also emotional and communicational values and could be considered as disfluencies as they precede, interrupt, and follow the discourse. Vlemincx and Luminet (2020) argue that sighs both induce and express relief, so that this psychological regulation of aversive states, also in cognitively demanding and stressful tasks, is a reason for conceiving of sighs as speaker-oriented disfluencies. However, sighs may also express a large array of (emotional, mental, or physical) states such as stress, relief, boredom, relaxation, weariness, satisfaction, resignation, self-encouragement, exasperation, sadness, love, frustration, hope, regret, surprise, impatience, and so forth (Li & Yackle, 2017; Poggi et al., 2018; Teigen, 2008). In other words, with many caveats, sighs might also be seen as listener oriented when they carry feelings along to the interlocutor. Listeners seem to rate correctly the valence (positive vs. negative) of sighs, but they may be wrong in labeling the exact state expressed by the sigh, for example, confusing a state of frustration versus giving up (Poggi et al., 2018). Sighs may also be used in a conscious way in order to communicate specific meanings to their interlocutor; in combination with body language, a sigh can be insulting or discrediting (Poggi et al., 2018). Here again, no data seem to be available for autistic speakers.

Finally, we propose that *laughter* can be viewed as a disfluency in some instances, as for example, when laughing interrupts the speech flow to signal embarrassment or a feeling of awkwardness (Mazzocconi et al., 2020). Laughter can function as a speaker-oriented distress marker, intended to induce some relief, but it can also be listener oriented in signaling the need for relieving pressure to the interlocutor (or "troubletelling"; Mazzocconi et al., 2020), and it is not inconceivable for these two functions to be filled at the same time. However, laughter is understudied in its relationship to other disfluencies and, furthermore, has been rarely studied in autism, and exclusively so in children. While autistic children seem to laugh as much as neurotypicals in playful situations (e.g., tickling, peek-a-boo, slapstick), they are reported to laugh less in response to events, such as funny faces or socially inappropriate acts, or in reaction to another person's laughter (Reddy et al., 2002). In the same vein, Hudenko et al. (2009) found acoustic differences in laughter between autistic and non-autistic children and suggested that autistics produce laughter in response to positive internal states, whereas non-autistics also use laughter in order to negotiate social interactions (also see Helt & Fein, 2016, for an analysis of facial feedback and social input effects). Another study found that non-autistic listeners tend to prefer laughter produced by autistic children in comparison with non-autistics, so that it could serve as an incentive to form relationships with them (Hudenko & Magenheimer, 2011). In this article, we will investigate the potential role of breath and laughter as disfluencies, without prejudging their speaker- or listener-oriented nature.

Variables That May Relate to Disfluencies

In this study, we also account for six variables that are seldom included in studies on disfluencies (in autism) despite being highly relevant: gender, social anxiety, alexithymia, experienced stress, social attention, and eye contact. Differences in speech production between non-autistic women and men have long been suggested and evidenced (Cohen, 2008; Haas, 1979; Mulac et al., 1988, 1990, 2001; Mulac & Lundell, 1986). As noted above, in autism, gender seems to play a role in the *um–uh* ratio. Unfortunately, gender is rarely taken into account in studying other disfluencies in autism. That said, research found that discourse in autistic women might be more neurotypical-like, potentially because of camouflage, leading to late diagnostic (McQuaid et al., 2021; Perry et al., 2021) and to better first impressions in non-autistic individuals (Cola et al., 2020). Better understanding of discourse patterns in autistic women might enlighten our knowledge of gender specificities in autism expression and improve diagnosis sensitivity.

While disfluencies may be quantitatively and qualitatively distinct in autism, they may also depend on two autism-related yet distinct factors: social anxiety (viz. fear of negative evaluation that leads to an excessive concern about social situations) and alexithymia (viz. difficulties in identifying and describing own emotions). Both are often attested in autistic adults (for reviews, see Kinnaird et al., 2019; Spain et al., 2018). It is possible, then, that group differences between autistics and neurotypicals at the level of disfluencies, especially in speaker-oriented ones, reflect social phobia or alexithymic traits, rather than being associated with autism per se.

However, Christenfeld and Creager (1996) questioned the nature of the link between anxiety and disfluencies; they found that speakers who were especially paying attention to their speech (i.e., students under evaluation; Broca's aphasics) produced more *um*s than those who were not particularly concerned by their speech production (i.e., speakers under the influence of alcohol; Wernicke's aphasics). Broen and Siegel (1972) found less disfluencies in situations where adult speakers thought fluent speech was important (so that they monitored their speech). This relationship between self-consciousness and disfluency production makes the investigation of alexithymic traits even more relevant; alexithymia has been tentatively associated with interoception as alexithymic individuals might have difficulties in perceiving the internal state of their body (Bird et al., 2010; Brewer et al., 2015; Shah et al., 2016).

Importantly, anxiety traits (i.e., general anxiousness) are not to be confused with anxiety state (i.e., responses to stressful situations). In everyday situations, stress is often adduced when it comes to excuse word retrieval difficulties and subsequent disfluencies, and some researchers have correlated stress to disfluency production (e.g., T. W. Buchanan et al., 2014). For this reason, to genuinely account for a potential influence of anxiety on speech, it is crucial to complement questionnaires with a physiological measure of stress. Electrodermal activity (EDA) is a peripheral index of the autonomic nervous system functioning (leading to fight or flight behaviors), easily measured through the skin conductance, that is, by changes in electrical conductivity in the skin over time (see Boucsein, 2012, for details). Skin conductance responses (SCRs) are reliable proxies of experienced arousal (Gaigg et al., 2018) and especially relevant for the present context, as they allow to link distress reactions in EDA to specific events, such as disfluencies.

Finally, social attention (i.e., whether the participant looks or not at the experimenter and whether the experimenter looks or not at the participant) and eye contact (i.e., the participant and the experimenter looking at each other's face at the same time) have not been controlled when studying disfluencies (Engelhardt, 2021). Yet, it is crucial to take into account eye gaze behaviors from both interlocutors in this context, for at least three reasons. First, disfluencies may be correlated to social attention. For example, turn-taking is organized by gaze, as someone may look at one's interlocutor to manifest that they want to take the floor (Kendon, 1967). However, autistic adults tend to look less at their interlocutor, so that they could miss or misinterpret interactional cues and produce disfluencies and gaze behaviors that do not synchronize with their conversational partner. Second, eye contact may potentially cause distress in autistics (or socially anxious individuals), which could, in turn, give rise to specific disfluencies (Buhr et al., 2017). Third, it has been shown that disengaging from eye contact can improve cognitive processes during face-to-face interactions (H. Buchanan et al., 2014; Kajimura & Nomura, 2016; Kendon, 1967; Kosmala & Morgenstern, 2019). Accordingly, whenever differences in disfluency production are found between autistic and neurotypical groups, it is important to know whether these differences are correlated with the conversational partner's attitude (direct vs. averted gaze) and the participants' gaze behaviors (fixations on the experimenter's face).

Summary and Outlook

The currently available literature suggests that when compared to neurotypical discourse, autistic adults' speech may exhibit less listener-oriented disfluencies (fillers, *um*) and more speaker-oriented disfluencies (repetitions, repairs), which may make their speech harder to follow. However, most disfluencies are not carefully classified, are understudied, or not studied at all in the autism field (e.g., false starts, prolongations, metalinguistic comments, breath, laughter). Moreover, the dichotomy between speaker- and listener-oriented disfluencies is far from self-evident. Indeed, although some disfluencies are quite unanimously accepted as pertaining to one category (e.g., fillers), others are taken to belong to listener-oriented disfluencies by some researchers but to speaker-oriented disfluencies by others (e.g., repetitions), and still others could theoretically belong to both categories (e.g., breath, laughter). Finally, many variables might have been insufficiently considered when studying disfluencies, such as gender, social anxiety, alexithymia, experienced stress, eye contact, and social attention.

Based on this review, our study addresses three main research questions. First, we ask whether autistics and neurotypicals produce different patterns of disfluencies, controlling for the experimenter's gaze, social anxiety, and alexithymia. We expect to find less fillers (in particular, *um*) and laughter but more repetitions and repairs in the speech of autistic adults. Direct gaze from the experimenter might increase the overall disfluency production rate, and especially in fillers, as the participants could interpret a constant direct gaze as signaling the intention to take the floor. However, autistics might be less sensitive to this direct gaze effect. Socially anxious participants might produce more disfluencies, especially in a direct gaze context, whereas alexithymia could be associated with less disfluencies.

Second, and subsequently to the first research question, we ask how potential differences in disfluency production between groups relate to gender, SCRs, or fixations on the experimenter's face. We expect to find gender-specific differences (e.g., less *um* in autistic men in comparison with autistic women and neurotypicals; more false starts in all men). We also expect SCRs to be correlated with disfluencies, especially with the speaker-oriented ones. Finally, we expect neurotypical participants to look more at the experimenter's face when producing listener-oriented disfluencies and to avoid the experimenter's face when producing speaker-oriented disfluencies. Autistic participants' attitude cannot be predicted based on the literature.

Third, as an exploratory analysis, we ask whether SCRs and gaze behaviors toward the experimenter could help consolidate the dichotomy between listener- and speaker-oriented disfluencies. We expect speaker-oriented disfluencies to correlate more with distress, as tapped by SCRs, and listener-oriented disfluencies to correlate with fixations on the experimenter's face—as we hypothesize that disfluencies specifically devoted to a conversational partner might go with more social attention.

Method

Experimental Task

Each participant individually sat down at a table in a quiet room, in front of an experimenter, and was instructed to define 20 words displayed on paper cards by the experimenter; participants were asked to avoid "dictionary-like" definitions and encouraged to rather explain how they understand and appropriate the words at hand (cf. Supplemental Material S1 for more details). As an example, the experimenter talked about the first word, then put down the card, unveiling the next word, and asked the participant to define it. The experimenter remained benevolently passive (i.e., serene, patient, and carefully listening); participants were warned that the experimenter would neither comment nor react to their answers. For one half of the participants in each group (autistics vs. neurotypicals), throughout the task, the experimenter consistently looked at the participant's eyes (direct gaze condition); for the other half, the experimenter consistently looked away from the participant (averted gaze condition). We intended to make this task interactional by putting our participants' image at stake; what they would say might inform the experimenter's opinion on who they are and how cultured they might be. In line with previous studies that have showed that autistics are concerned for their reputation (e.g., Cage et al., 2016a, 2016b), several autistic participants appeared concerned about the social evaluation of their performance during and after the experiment (*I must appear so stupid*; *I have forgotten to talk about…*). However, by using this specific paradigm, we aimed at preventing participants from experiencing stress because of the setting in three respects: First, it does not highlight the socioemotional value of the encounter; second, its structure is highly predictable; and third, it is not cognitively overloading, as our participants were prompted to say anything that was passing by their minds, without any objective evaluation.

Apparatus

Participants' eye movements were recorded (at a 100-Hz rate) with Tobii Pro Glasses 2, a wearable eye-tracker. It provided us with binomial variables, which indicated whether the experimenter's eyes, face, or body were fixated or not. Data quality has been checked: We reached 84% of valid data, and data quality in both groups is broadly similar (see Table 1). Participants' skin conductance was recorded (at a 15-Hz rate) by Shimmer3 GSR+ sensors attached with hook-and-loop fastener straps on the palmar side of the proximal phalange of their index and medium fingers of their nondominant hand. Every skin conductance difference comprised between 0.1 and 1 μSiemens between two values separated by 1 s and followed by a recovery time was coded as a "skin conductance response." See Figure 1 for a picture of the setting. Participants' definitions were recorded with a camera (Sony FDR-AX33 4 K) and a professional microphone (Røde Videomic Pro). They were then coded by disfluency type (*um*, *uh*, discourse markers, prolongations, comments, repairs, false starts, repetitions, breath, laughter). Coding and revising were carried out by two coders whose double-coding reached a high level of agreement (total κ = 0.92). See Supplemental Material S1 for data preparation and synchronization details.

Participants

Participant characteristics are reported in Table 1. The autistic group was composed of 40 adults (20 women, 20 men), aged 20–55 years (M = 36.25; SD = 9.98), and

Table 1. Participant characteristics.

	Autistic group (n = 40; F = 20)		Neurotypical group (n = 40; F = 20)		
	Direct gaze (n = 20; F = 10)	Averted gaze (n = 20; F = 10)	Direct gaze (n = 20; F = 10)	Averted gaze (n = 20; F = 10)	
Measures	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**	***F***
Data quality	78.9 (15.9)	88.1 (7.2)	84.6 (7.9)	84.8 (9)	2.62
Age (years)	36.1 (10.3)	36.4 (10)	36.1 (11.6)	36.4 (11.3)	0.006
Full-scale IQ	116.8 (16.1)	120.2 (15.5)	118.6 (10.8)	119 (7.6)	0.23
Verbal IQ	118.6 (13.8)	130.1 (15.4)	125.5 (11.2)	127.4 (14.5)	2.48
Education level	3.2 (1.2)	3.3 (1.6)	3.8 (1)	3.5 (1.1)	0.95
Economic status	6.8 (2.2)	5.6 (1.8)	7.9 (1.7)	7 (2.2)	4.49**
Autism quotient	38.2 (5.8)	39.1 (5.4)	17.6 (6.1)	16.4 (6.6)	88.21***
Empathy quotient	20.1 (8.1)	21.5 (9.2)	43.4 (10.7)	44 (11.3)	35.71***
Social anxiety	78.3 (25.2)	85.1 (20.9)	34.7 (23.2)	40.7 (23.3)	22.63***
Alexithymia	61.5 (8.9)	61.3 (12.1)	45.3 (10.8)	46.6 (8.7)	14.1***

Note. F values come from one-way analysis of variances on the four groups with Tukey post hoc multiple comparison tests. Missing data: two verbal intellectual quotients and one economic status and level of education (autistic group); six social anxiety and alexithymia questionnaires (autistic group: two; neurotypical group: four).

**p < .01. ***p < .001.

Figure 1. Picture of the experimental setting. (Left) A participant wearing eye-tracking glasses and electrodermal activity sensors. (Right) The experimenter setting up the eye-tracking glasses software.

groupwise matched by full-scale and verbal intellectual quotients, as assessed by Wechsler Adult Intelligence Scale IV (WAIS-IV; Wechsler, 2008), to a neurotypical group consisting of 40 adults (20 women, 20 men), aged 21–55 years (*M* = 36.23; *SD* = 11.33). For every recruited autistic participant, another autistic and two neurotypicals were recruited: The four were pairwise matched by age and gender and dispatched into four subgroups, following a Group (autistic vs. neurotypical) × Condition (direct vs. averted gaze) design.

Participants were recruited through our laboratory database, flyers (published on social media or pinned in public places), and personal networks. Inclusion criteria were being a native French speaker, being verbally fluent, not stuttering, having no intellectual delay, and having normal or corrected-to-normal vision and audition. All autistic participants received a clinical diagnosis of autism or Asperger syndrome from multidisciplinary teams (composed of medical doctors, psychologists, and social workers) specialized in diagnosing autism and officially habilitated to do so by the Belgian State, based on the Autism Diagnostic Observation Schedule (Lord & Jones, 2012) and the Autism Diagnostic Interview–Revised (Rutter et al., 2003) criteria. To be included in the neurotypical group, participants needed to have no history of developmental delays, psychiatric diagnoses, or neurocognitive impairments. There was a minority (*n* = 9 in both groups) of simultaneous bilinguals (Paradis et al., 2021).

Participants were asked to complete five predesigned self-administered questionnaires: the Adult Autism Spectrum Quotient (Baron-Cohen et al., 2001); the Cambridge Behaviour Scale (Baron-Cohen & Wheelwright, 2004), assessing the empathy quotient; the Liebowitz Social Anxiety Scale (Liebowitz, 1987), identifying three levels of social anxiety (mild, moderate, or severe); the 20-item Toronto Alexithymia Scale (Bagby et al., 1994), grouping participants into three alexithymia profiles (not alexithymic, potentially alexithymic, and alexithymic); and our laboratory questionnaire, adapted from the revised Family Affluence Scale (Currie et al., 1997, 2008; Hartley et al., 2016; Torsheim et al., 2016). The latter provides a proxy for the participant's socioeconomic background: The education score is a 0- to 6-point scale (0 being *no primary school achieved*; 6 being *doctoral degree*), and the economic status score is a 0- to 13-point scale (0 being *very low*; 13 being *very high*). Note that we did not attempt to match our groups by the socioeconomic variables; autistics, even if they are intellectually able, often encounter difficulties in their academic and working lives because of their autism, which can negatively impact their socioeconomic status (e.g., Davies et al., 2023).

Data Acquisition

All the adults were individually evaluated by a trained master's student in neuropsychology (*n* = 75), blind to participants' diagnosis and to the aims of the study, or by the first author (*n* = 5). To maximize data quality, participants were encouraged to come to our laboratory, and most did (*n* = 55). However, some participants could not visit the laboratory, for personal or practical reasons, and were thus tested at their home (*n* = 25), in a quiet and comfortable room. Overall, only six interruptions occurred during the task (e.g., a participant's cat jumping on the table; the postman knocking at the door). Interrupted trials were discarded. Data reported here were collected at the beginning of an experimental session, before three other tasks. When a WAIS-IV IQ score no older than a year was not available, the IQ test was administered during another experimental session.

Statistical Methods

All statistical analyses were implemented in R (R Core Team, 2019). The independent variables were group (autistic vs. neurotypical), condition (direct vs. averted gaze), gender (female vs. male), and disfluency type (*um*, *uh*, discourse markers, prolongations, comments, repairs, false starts, repetitions, breath, laughter). The dependent variables were disfluency proportion (proportion of each disfluency type per item and participant), face (proportion of fixations on the experimenter's face when a specific disfluency type occurs, per item, participant, and disfluency type), and SCRs (proportion of SCRs when a specific disfluency type occurs, per item, participant, and disfluency type). Because of the synchronization process (see Supplemental Material S1 for details), disfluencies were coded as durations instead of occurrences, so that the proportions expressed here correspond to the portions of time when a disfluency type occurred within the total duration of the participant's speech during each trial. The control variables were social anxiety scores and alexithymia scores.

The variables were analyzed with forward stepwise multilevel linear regressions, with by-participants and by-items intercepts in the random structure, using the lme4 (Bates et al., 2015) and the lmerTest (Kuznetsova et al., 2017) packages. We started from the null model and incrementally augmented it with group, condition, and their interaction, keeping the random structure unchanged, until we reached the theoretically motivated maximal model. Post hoc comparisons of least-square means were carried out with the emmeans package (Version 1.4; Lenth, 2019) with Tukey adjustment for multiple comparisons. Figures were created using the effects (Fox & Weisberg, 2019), the ggplot2 (Wickham, 2016), and the gridExtra (Version 2.3; Auguie, 2017) packages.

Analytic Plan

To answer our first research question, regarding the specificities of disfluency patterns in autistics and neurotypicals, we checked whether there were group differences in the production of disfluencies and whether there was a Group × Condition (direct vs. averted gaze) interaction; we then controlled the maximal model for social anxiety and alexithymia. To answer our second research question, regarding potential factors influencing disfluency production, we investigated possible correlations with gender, SCRs, and fixations on the experimenter's face for all the disfluency types for which we found a group difference in answering our first research question. To answer our third research question, regarding the possibility to objectively classify disfluencies as listener or speaker oriented thanks to eye-tracking and EDA data, we investigated potential correlations between the production of each disfluency, SCRs, and rates of fixations on the experimenter's face.

Results

First Question: Disfluency Production

To determine whether speech of autistics differs from that of neurotypicals by different disfluency patterns, we first tested whether disfluency type, group, or condition predicts the proportion of disfluency. Figure 2 displays the proportions of disfluency by type, group, and condition.

Stepwise comparisons of multilevel models revealed that the addition of disfluency type significantly improved the model fit, $\chi^2(9) = 5362.52$, $p < .001$, as did the Disfluency Type × Group interaction, $\chi^2(9) = 119.2$, $p < .001$; the Disfluency Type × Condition interaction, $\chi^2(9) = 48.58$, $p < .001$; and the Disfluency Type × Group × Condition interaction, $\chi^2(9) = 131.63$, $p < .001$. Adding social anxiety or alexithymia as fixed factors to the maximal model did not improve its fit (both *p*s > .689).

Post hoc pairwise comparisons on the maximal model indicated that neurotypicals were more likely than autistics to produce *um* fillers in both the direct ($\beta = .01$, $SE = 0.4e^{-2}$; $p = .049$) and the averted ($\beta = .01$, $SE = 0.4e^{-2}$; $p = .026$) gaze conditions. Neurotypicals were also more likely than autistics to produce *uh* fillers in the direct gaze condition ($\beta = .01$, $SE = 0.3e^{-2}$; $p = .002$) but less likely than autistics to produce *uh* fillers in the averted gaze condition ($\beta = .01$, $SE = 0.3e^{-2}$; $p = .042$). Autistics were more likely to produce *uh* fillers in the averted than in the direct gaze condition ($\beta = .01$, $SE = 0.3e^{-2}$; $p < .001$). Neurotypicals were also more likely than autistics to produce prolongations in the averted gaze condition ($\beta = .01$, $SE = 0.3e^{-2}$; $p = .009$). Autistics were less likely to produce prolongations in the averted than in the direct gaze condition ($\beta = .01$, $SE = 0.3e^{-2}$; $p = .01$). Autistics were more likely than neurotypicals to produce breath in the direct gaze condition ($\beta = .02$, $SE = 0.4e^{-2}$; $p < .001$). Autistics were also more likely to produce breath in the direct than in the averted gaze condition ($\beta = .01$, $SE = 0.4e^{-2}$; $p = .012$). By contrast, there was no difference in disfluency production by group or condition with respect to discourse markers, repetitions, repairs, false starts, laughter, and comments (all *p*s > .15). All these differences are summarized in Tables 2 and 3.

Second Question: Gender, SCRs, and Fixations

Next, we investigated potential factors underlying the group differences just reported. We checked whether differences in disfluency production of *um*, *uh*, prolongations, and breath are correlated with gender (see Figure 3), SCRs (see Figure 4), or fixations on the experimenter's face (see Figure 5).

Figure 2. Proportions of disfluency per type, group, and condition.

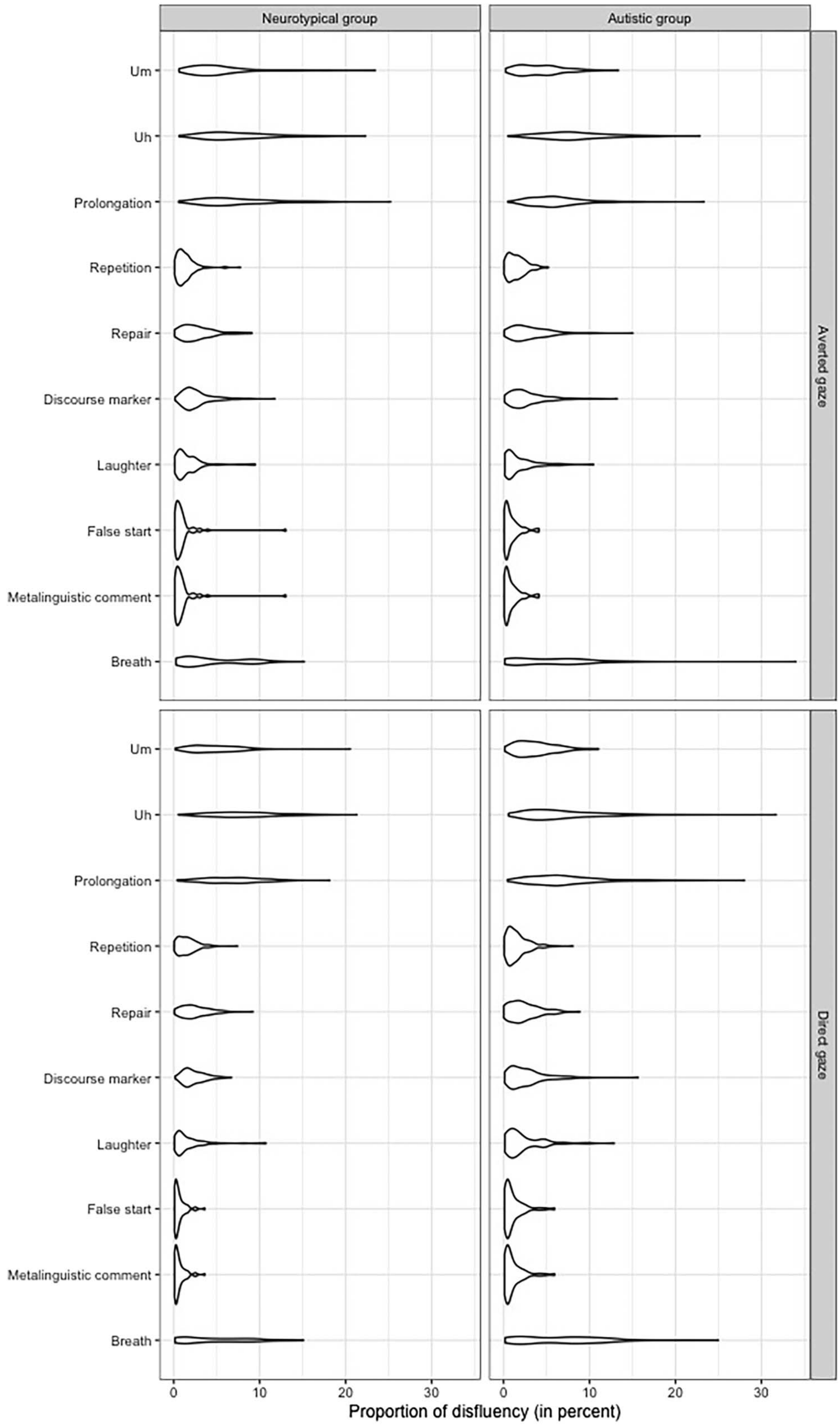


Table 2. Summary of group differences in disfluency production by condition.

Disfluency	Condition	Group difference
Um filler	Direct gaze	Neurotypical > autistic
	Averted gaze	Neurotypical > autistic
Uh filler	Direct gaze	Neurotypical > autistic
	Averted gaze	Neurotypical < autistic
Prolongation	Averted gaze	Neurotypical > autistic
Breath	Direct gaze	Neurotypical < autistic

To determine whether group, condition, or gender predicts the production of *uh*, *um*, prolongations, and breath, we conducted four stepwise comparisons of multilevel models, one for each disfluency type of interest. These models revealed no difference in gender between groups or conditions in producing *uh*, prolongations, and breath (all *p*s > .05). However, stepwise comparisons of multilevel models indicated that the addition of group significantly improved the *um* model fit, $\chi^2(1) = 6.27$, $p = .012$, as did gender, $\chi^2(1) = 8.53$, $p = .003$. Post hoc pairwise comparisons indicated that women were more likely than men to produce *um* fillers ($\beta = .01$, $SE = 0.4e^{-2}$; $p = .005$). Then, we asked whether disfluency type (only keeping *uh*, *um*, prolongations, and breath), group, or condition predicts SCRs. Stepwise comparisons of multilevel models revealed no difference between groups, conditions, or disfluency types in SCRs (all *p*s > .09). Finally, we asked whether disfluency type (only keeping *uh*, *um*, prolongations, and breath), group, or condition predicts fixations on the experimenter's face. Stepwise comparisons of multilevel models revealed that the addition of Disfluency Type × Group × Condition significantly improved the model fit, $\chi^2(3) = 9.8$, $p = .02$. However, post hoc pairwise comparisons indicated no difference between groups, conditions, or disfluency types in fixating the experimenter's face (all *p*s > .57).

Third Question: Speaker- Versus Listener-Oriented Disfluencies

To contribute to the classification between listener- and speaker-oriented disfluencies and as an exploratory analysis, we looked for correlations between disfluency production and our participants' experienced stress and actual gaze behaviors toward the experimenter. On the one side, we asked whether disfluency type (all categories included), group, or condition predicts the proportion of SCRs. Stepwise comparisons of multilevel models revealed no difference in SCRs between disfluency types, groups, or conditions (all *p*s > .113).

Table 3. Summary of condition differences in disfluency production by group.

Disfluency	Group	Condition difference
Uh filler	Autistic	Direct gaze < averted gaze
Prolongation	Autistic	Direct gaze > averted gaze
Breath	Autistic	Direct gaze > averted gaze

On the other side, we asked whether disfluency type (all categories included), group, or condition predicts the proportion of fixations on the experimenter's face. Stepwise comparisons of multilevel models revealed that the addition of disfluency type significantly improved the model fit, $\chi^2(9) = 268.7$, $p < .001$, as did the Disfluency Type × Condition interaction, $\chi^2(9) = 34.24$, $p < .001$. Post hoc pairwise comparisons indicated that participants were more likely to look at the experimenter's face when producing laughter in the direct than averted gaze condition ($\beta = .04$, $SE = 0.01e$; $p = .015$). Also, participants were more likely to look at the experimenter's face when producing laughter than any other disfluency in both the direct and averted gaze conditions (all *p*s < .001). Interestingly, participants were less likely to look at the experimenter's face when producing *um* fillers than other disfluencies (discourse markers, repetitions, and prolongations) in the direct gaze condition only (all *p*s < .006).

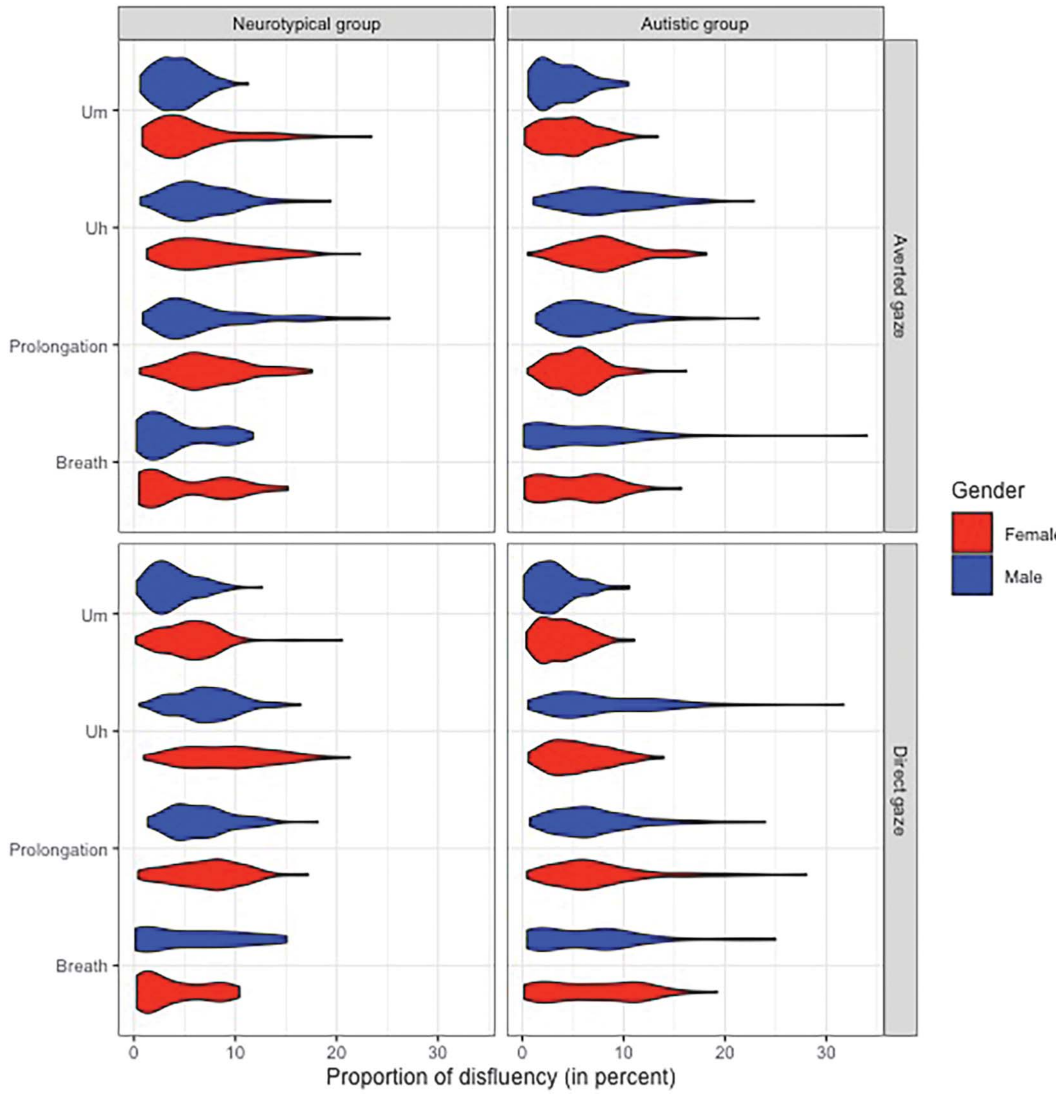
Discussion

Our live face-to-face paradigm simultaneously assessed autistic and neurotypical participants' discourse behavior—disfluencies—in relation with eye behaviors and SCRs, in front of an experimenter with a direct gaze or an averted gaze.

Our first research question addressed group differences in the production of disfluencies. We found that autistics produced less *um* than neurotypicals in both conditions (experimenter's direct and averted gaze). This result is congruent with previous studies (Gorman et al., 2016; Heeman et al., 2010; Irvine et al., 2016; McGregor & Hadden, 2018). We also found that women from both groups produced more *um* fillers than men. On the one hand, this latter results gel well with previous studies that indicated that autistic women do not differ from neurotypical women in their production of *um* (McGregor & Hadden, 2018; Parish-Morris et al., 2017), suggesting a camouflage effect that could lead to later diagnosis. On the other hand, however, unlike in these studies, our autistic male participants were close to neurotypical men in producing less *um* than women.

We also found that participants were modulating their production of *uh* fillers depending on the condition; autistics were producing less *uh* in the direct than in the averted gaze while neurotypicals were producing more *uh* in

Figure 3. Proportions of disfluency per type, group, condition, and gender.

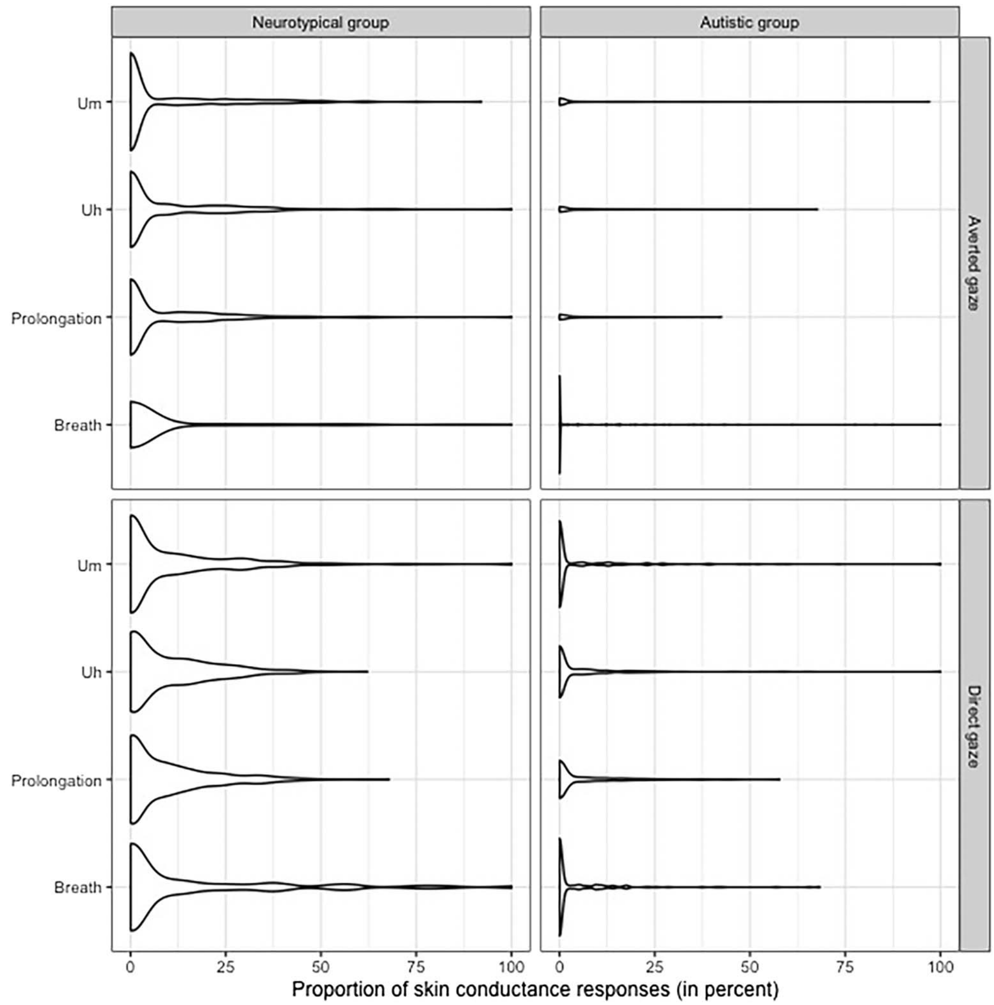


the direct gaze than autistics and less *uh* in the averted gaze than autistics. These results seem to confirm that *uh* fillers are listener-oriented disfluencies, as suggested by most researchers (Engelhardt, 2021); depending on the interlocutor's attitude (looking or not at the participant), *uh* fillers are produced at a different rate. That being said, autistics seem to also behave unlike neurotypicals in that they increase their production of *uh* when the experimenter is looking elsewhere and not when s/he is paying attention to them (recall that direct gaze can be interpreted as the will to take the floor, while *uh* fillers allow to keep the floor).

We also found that autistics produced more prolongations in the direct than in the averted gaze condition, whereas neurotypicals displayed the opposite pattern in producing more prolongations in the averted than in the direct gaze. Nonpathological prolongations are clearly understudied in autism, and no group difference has yet been reported (Engelhardt, 2021; Wiklund & Laakso, 2021). Our results question the status of prolongations; if the direct gaze condition does indeed highlight the social nature of the encounter, so that we could expect more listener-oriented disfluencies to be produced in this context, the fact that neurotypicals produced more prolongations in the averted compared to the direct gaze condition would rather suggest that they are speaker oriented. Further studies, including measures of the "communicational helpfulness" of prolongations in social interactions, are clearly needed to elucidate their status.

Finally, we found that, in the direct gaze condition, autistics were producing more breath than neurotypicals

Figure 4. Proportions of skin conductance responses per disfluency type, group, and condition.

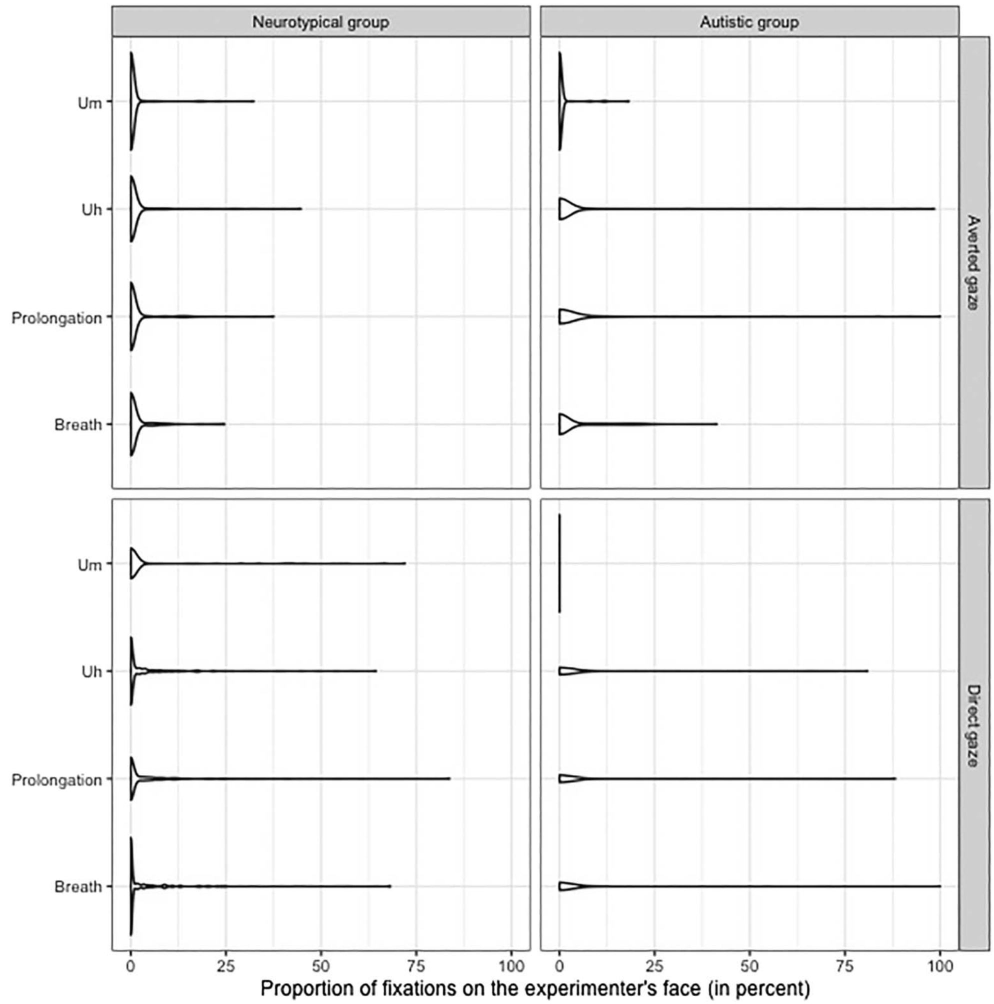


and also more breath than in the averted gaze condition. Here again, breath is understudied, but from a theoretical point of view, it makes sense to treat breaths as carrying a speaker-oriented value; while breaths can express a large array of states (Li & Yackle, 2017; Poggi et al., 2018; Teigen, 2008), their first likely role is to induce relief in cognitively demanding situations (Vlemincx & Luminet, 2020).

That autistics produce less listener-oriented (*uh*, *um*) and more (presumed) speaker-oriented (prolongations, breath) disfluencies than neurotypicals could contribute to the judgment of atypicality autistic and non-autistic raters rapidly form about autistic speakers (Geelhand et al., 2021; Lim et al., 2021; Sasson et al., 2017). Yet, our results also show that autistics are sensitive to their interactional partner's behavior. Even though direct or averted gaze conditions had opposite effects on autistics than on neurotypicals, autistics also modulated their speech depending on whether their conversational partner systematically looked at them in the eyes or not. This suggests an atypical reaction to social signals. As reported in the introduction, eye contact may cause distress (Buhr et al., 2017), and disengaging from eye contact can improve cognitive processes (H. Buchanan et al., 2014; Kajimura & Nomura, 2016; Kendon, 1967; Kosmala & Morgenstern, 2019). One hypothesis could be that an absence of direct gaze might help autistics to focus on their partner and produce more listener-oriented disfluencies (such as *uh*). Conversely, direct gaze may make word description more demanding for autistics and thus cause more speaker-oriented disfluencies (such as prolongations and breath).

Our second research question was whether potential factors could be correlated to these disfluency production patterns. Experienced stress (i.e., SCRs), social attention (i.e., fixations on the experimenter's face), and

Figure 5. Proportions of fixations on the experimenter's face per disfluency type, group, and condition.



alexithymia and social anxiety scores did not influence any of the reported results. However, group differences in disfluency production were observed within the disfluency categories that were produced at the highest rates, so that the absence of difference in producing other disfluencies could be due to a floor effect. While further investigation is certainly warranted, our preliminary results do suggest that disfluencies might primarily be linguistic phenomena and that group differences mostly depend on speech processes rather than on other variables.

Our third research question addressed whether SCRs and participants' eye gaze behaviors might contribute to the classification between speaker- and listener-oriented disfluencies. This exploratory analysis revealed that participants were fixating more on the experimenter's face when laughing in both the direct and the averted gaze conditions, as compared to all the other disfluency types. Moreover, laughter was, overall, produced more in the direct than in the averted gaze condition. Recall that laughter is considered in this specific paradigm (where the participant is talking without any feedback) as a disfluency, as it interrupts the speech flow, instead of being a shared moment of cheerfulness. This pleads in favor of a listener-oriented status of laughter, signaling embarrassment or awkwardness in a socially uncomfortable moment, and requesting a pressure relief (Mazzocconi et al., 2020).

We also found that, in the direct gaze condition only, *um* fillers were eliciting less fixations on the experimenter's face than other disfluencies. That would confirm the generally admitted difference between *uh* and *um* fillers (e.g., McGregor & Hadden, 2018), where *um* would denote, in addition to its delay-signaling virtue (i.e., listener-oriented value), a more important cognitive load (i.e., speaker-oriented value) that would require a potential reduction of eye contact to improve the cognitive processes (H. Buchanan et al., 2014; Kajimura & Nomura, 2016; Kendon, 1967; Kosmala & Morgenstern, 2019). Note that our paradigm might have reduced the total amount of fixations on the experimenter, so that we could have missed more subtle effects. Indeed, people display more fixations on speaking versus listening interactional partners (Freeth & Bugembe, 2019; Freeth et al., 2013; Gobel et al., 2015; Haensel et al., 2020; Hessels et al., 2019; Vabalas & Freeth, 2016), and in our task, participants were the ones who did most of the talking. The same limitation applies to EDA measures; the task we employed (defining words) involved only minimal social interaction. Even though, in postexperimental debriefing, several autistic participants appeared concerned about the social evaluation of their performance (*I must appear so stupid*; *I have forgotten to talk about…*), it makes sense to speculate that participants' EDA would be different in more socially demanding contexts, so that SCRs could prove useful in distinguishing listener- versus speaker-oriented disfluencies in other contexts.

Limitations and Future Directions

Data were collected among a sample of autistics with linguistic and intellectual profiles within the typical range, so that the results reported here should not be extended to the whole autism community. A comprehensive description of disfluencies, be it in neurotypical or autistic speech, requires a multipronged methodology. This study did include a fine-grained typology of speaker- and listener-oriented disfluencies whose frequency was assessed against several theoretically motivated variables: gender, eye contact, social attention, experienced stress, alexithymia, and social anxiety. However, many more dimensions should be investigated in future research. For instance, context of use could be manipulated more directly: Negotiating the floor in a one-on-one meeting is very different from speaking out a prepared speech in a podcast or being involved in a family dinner. One may think of other variables, such as familiarity between interlocutors, discussed topics, and effect on interactional partners' comprehension and well-being. Some disfluencies may also be task dependent; to elicit disfluencies that were underrepresented in this study, one could imagine paradigms that target specific discourse patterns. For example, during experiment briefing, insisting on correctness/precision of the production might elicit more false starts and repairs, while likability would probably elicit more listener-oriented disfluencies.

Conclusions

We found that autistics produced less listener-oriented (*uh*, *um*) and more speaker-oriented (prolongations, breath) disfluencies than neurotypicals, which could contribute to the impressions of an atypical discourse. We also found that autistics and neurotypicals were sensitive to their interlocutor's attitude (displaying direct vs. averted gaze), but their reactions went in opposite directions. This latter result suggests that autistics might have an atypical sensitivity to social signals, instead of a social indifference or insensitivity. In this sense, our findings gel well with the double empathy perspective on autism (Milton et al., 2021). Autistics' use of disfluencies might not fit neurotypicals' expectations, whereas neurotypicals might not understand the autistics' communicative intent, contributing to a reduced synchronization between interactional partners. Finally, our results suggest that, in the future, eye-tracking and EDA could be used to further distinguish between listener- and speaker-oriented disfluencies and therefore represent a promising way to assess types of issues (interactional vs. cognitive) encountered by people with unusual use of disfluencies, leading to more specific support.

Declarations

Ethics Approval and Consent to Participate

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee (Erasme-ULB Ethics Committee, approval code: P2018/625 / CCB B406201838210) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Participants gave their written consent to be involved in this study after having been informed of their rights and all aspects of the sessions (number, length, content, and collected data).

Consent for Publication

Written informed consent for publication of their photographs was obtained from first author and the participant.

Author Contributions

Elise Clin: Conceptualization (Lead), Data curation (Lead), Formal analysis (Lead), Funding acquisition (Equal), Investigation (Lead), Methodology (Lead), Project administration (Lead), Resources (Lead), Software (Lead), Validation (Lead), Visualization (Lead), Writing – original draft (Lead), Writing – review & editing (Lead). **Mikhail Kissine:** Conceptualization (Supporting), Formal analysis (Supporting), Funding acquisition (Equal), Resources (Supporting), Supervision (Lead), Writing – original draft (Supporting), Writing – review & editing (Supporting).

Data Availability Statement

The data sets generated and analyzed during this study are available from the corresponding author on reasonable request.

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