Making Sense of Laughter:

a comparison of self-reported experience, perception and production in autistic and non-autistic adults

Qing Cai

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Doctor of Philosophy in Cognitive Neuroscience

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I, Ceci Qing Cai, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Abstract

Laughter has primarily been viewed as positive emotional vocalisation associated with humour and amusement. It is commonly used as a communicative tool in social interaction. Our mentalising network automatically engages in laughter processing to understand other people's laughter. However, autistic individuals struggle with social communication, driven by their difficulty mentalising. Therefore, this thesis investigated how the self-reported experience, perception and production of laughter differ between non-autistic and autistic adults:

Compared to non-autistic adults, autistic adults reported that they laugh less, enjoy laughter less and find it more difficult to understand other people's laughter. However, autistic adults reported that they laugh on purpose as often as non-autistic adults via a questionnaire study.

Autistic adults show a different pattern of laughter production relative to non-autistic adults. A multi-level dyadic study found that non-autistic pairs laughed more when interacting with their friend than a stranger, whilst the amount of laughter produced by pairs of one autistic and one non-autistic adult was not affected by the closeness of the relationship.

An explicit processing task found subtle differences in differentiating the authenticity of laughter and perceiving its affective properties between the two groups. Moreover, the addition of laughter increased non-autistic adults' perceived funniness of humorous stimuli; and they found humorous stimuli funnier when paired with genuine than posed laughs. However, this effect was not consistently observed in autistic adults. A follow-up fMRI study investigated the neural mechanism of implicit laughter processing and how these abilities relate to mentalising ability; subregions in

the prefrontal cortex showed greater activation while processing words paired with posed laughter than with real laughter in non-autistic adults but not in autistic adults.

In summary, this thesis demonstrated different patterns of laughter behaviour between autistic and non-autistic adults, including self-reported laughter experience, laughter production in social situations, laughter processing and its underlying neurocognitive mechanism. It extended our current understanding of the social-emotional signature of laughter from non-autistic adults to autistic adults and therefore highlighted the critical role of laughter in social interaction.

Impact Statement

My PhD work has highlighted the socio-emotional signature of laughter in social communication, and it further extended our current understanding of laughter from non-autistic adults to autistic adults.

Throughout five studies, the author investigated how the self-reported laughter experience, laughter production, laughter processing and its neural connection differed between non-autistic and autistic adults and proposed that the differences are associated with autistic adults having difficulties in social communication due to poor mentalizing ability.

In a series of experiments, the author has used a number of novel methods and new techniques in cognitive neuroscience and psychology study, including the multi-level dyadic design, explicit and implicit measures, and fMRI. Such new approaches provided more information than traditional psychological measurements used in laughter and autism research and helped to solve the unanswered questions ongoing in this field. By virtue of these improvements, it is revealed that important role of laughter in social interaction, especially in establishing and maintaining social bonds. It also advocates the use of clear communication signals with autistic people

The findings of the thesis will impact upon other autism and laughter researchers in terms of my research findings, clinicians involved in the diagnosis and assessment of autism and in interventional programs, and people supporting autistic people, including those in education, support services, parents and families. It also sheds light on research focusing on other psychology researchers through the development of new methods.

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1.1 Laughter as a universal emotional vocalisation

1.1.1 Laughter in mammals

Laughter and laugh faces have been universally recognised and observed in mammals during play (Davila-Ross et al., 2011; Davila-Ross & Palagi, 2022; Panksepp & Burgdorf, 2003; Ross et al., 2009). For instance, Davila-Ross and Palagi (2022) coded for muscle activations of six carnivore taxa with regard to their open-mouth faces of play; and they found these carnivore expressions are homologues of primate open-mouth faces of play.

Besides expressing positive affective in play, laugh vocalisation in mammals also show the difference in play contexts and is likely to act as communicative signals in social situations. Knutson et al. (1998) found rats frequently produced 50kHz ultrasonic vocalisations (USV) when tickled by experimenters, which is similar to the type of calls they produced when playing with other rats. This finding indicates that rats emitted positive calls/vocalisation during play which signified their desire for social interaction (Knutson et al., 1998). Burke et al. (2022) further illustrated that this positive calls/vocalisation is influenced by social contexts: male rats emitted 22 kHz USV around two times more frequently when ticking by the experimenter than playing with another rat, however, the rats were highly unlikely to emit calls when not engaged socially. Although the calls/vocalisation emitted by rats might be contextualised differently (Burke et al., 2022), both types of play calls/vocalisation were considered as an expression of a positive affective state and served as communication signals in some situations in rats (Burke et al., 2022; Knutson et al., 1998; Panksepp, 2005). In addition, the play calls emitted by juvenile rats are thought to be a homologue of human laughter which can be observed extensively during social play in human childhood (Knutson et al., 1998; Panksepp, 2005).

Laugh-like vocalisations accompanied by open-mouth faces (play faces) are commonly found in great apes in reaction to being tickled and within the context of play. Strikingly, it shows similarities with human laughter in evolution and social function basis (Davila-Ross et al., 2011; Davila-Ross & Palagi, 2022; Ross et al., 2009). Davila-Ross et al. (2009) remarkably revealed a homologous acoustic and phylogenetic profile of tickling-induced vocalisations in immature great apes and human infants, evidencing that tickling-induced laughter is from a common evolutionary origin in primates. In another study, Davila-Ross et al. (2011) found chimpanzees replicate the laughter produced by their partners during social play, and this laugh-elicited laughter is distinct in acoustic form and occurrence from their spontaneous laughter, suggesting that laugh-elicited laughter provides chimpanzees with predominant social benefits by helping them to promote especially to prolong their social play (Davila-Ross et al., 2011; Matsusaka, 2004). Interestingly, the laugh-elicited laughter of chimpanzees shows a similarity to the conversational laughter of humans, particularly in its unique role in promoting social interactions and social coordination (R. Dunbar & Mehu, 2008; Scott et al., 2014; Vettin & Todt, 2004)

Together, these findings provide evidence in support of shared ancestry of laughter and open-mouth laugh faces among primates and other mammals. In other words, the evolution of human laughter ‘evolved within the context of social play in pre-human times and was already complex in both form and function when produced by ancestral species’ (Davila-Ross & Palagi, 2022, p. 3). Furthermore, as an expression of positive affect, laughter serves as a salient signal of promoting social bonding across species (Davila-Ross & Palagi, 2022).

1.1.2 Laughter in human beings

Human laughter appears at about the fourth month of life and increases in frequency over time (Provine, 2012, 2004; Sroufe & Wunsch, 1972). It is a stereotypic non-verbal vocalisation, characterised by the signature sequences of regular short bursts of exhalations, vowel-like elements (e.g. /ha-ha/), and rhythmic breathing (Provine & Yong, 1991). Unlike speech which shows a fine pattern of intercostal muscle movements, the distinctive prosodic pattern of laughter is orchestrated by the rapid contraction of expiration muscles, which push the air stream through the larynx, where the vibration of vocal cords determines the fundamental frequency of the laughter(Ruch & Ekman, 2001). The minimal movement of the few articulators, such as the oral cavity and jaw, in turn, shaped the varied expression of laughter (Alter & Wildgruber, 2018; Ekman et al., 1990; Ruch & Ekman, 2001) (see Figure 1.1).

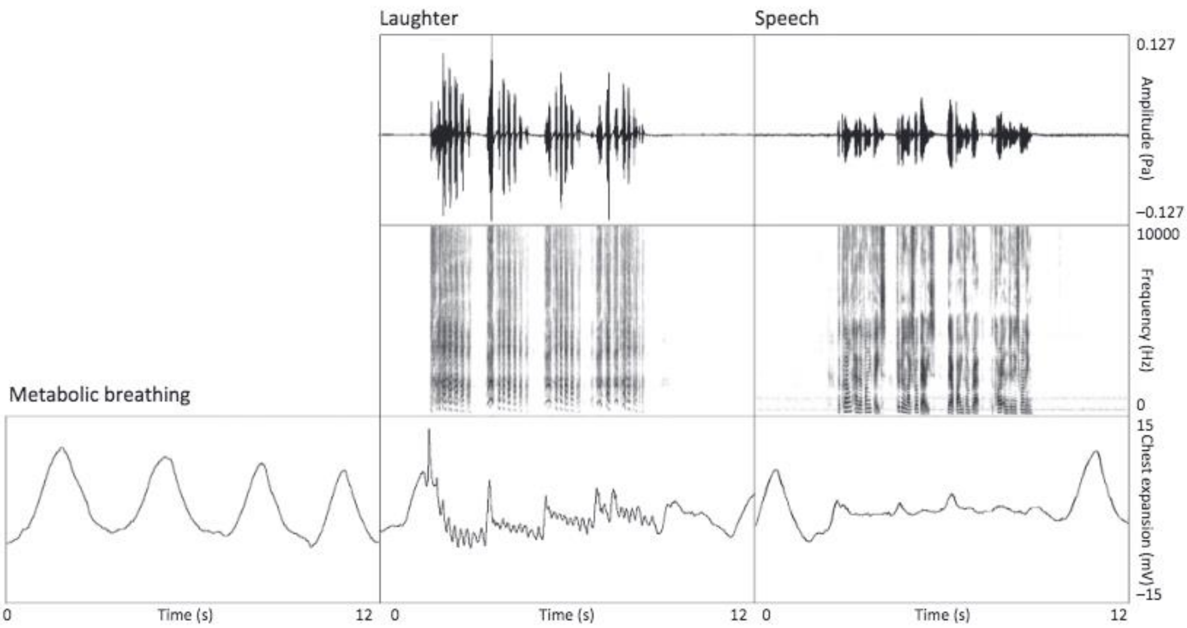


Figure 1.1 Metabolic breathing, speaking and laughing (Scott et al., 2014)

It is worth noting that laughter is the only positive emotional vocalisation that is universally recognised across cultures (Sauter et al., 2010). Sauter et al. (2010)

examined the cross-cultural reorganisation of communicative affect contained in emotional vocalisations between European native English speakers and Himba (a remote seminomadic society in northern Namibia having little contact with modern Western culture). Surprisingly, the sounds of laughter communicated amusement as the only positive vocalisation that was agreed upon by listeners in both groups. The cross-cultural finding on ubiquitous recognition of laughter provides empirical evidence that laughter is a social behaviour with deep evolutionary roots (Ruch & Ekman, 2001).

The nature of human laughter is highly behavioural contagious. People are 30 times more likely to laugh when we with others than being alone (Provine, 2004), and laughter can be easily elicited by hearing another other laughter (Provine, 1992). Additionally, the contagious-laughter effect is strongly mediated by social contexts (Provine, 1992). For instance, the amount of laughter is positively correlated with a group or audience size and the degree to which the involved individuals have an intimate/familiarity relationship (Bachorowski et al., 2001; Provine, 1992, 2004). Scott et al. (2022) further proposed that contagious laughter is possibly a unique nature in humans. Unlike apes, who produce laugh-elicited laughter only when physically engaged in play with others, humans (even in infancy) can provoke laughter and respond to others' laughter in the absence of direct physical contact (Scott et al., 2022).

Throughout laughter research, human laughter has long been viewed as an uncontrolled and genuine emotional vocalisation elicited by tickling and humour (Gervais & Wilson, 2005; Provine, 2004). Intriguing, however, laughter predominately exists in casual conversation. In an observational study, Vettin & Todt (2004) found participants laughed more frequently in conversation, and the amount of laughter participants produced in conversation was much more frequent than indicated in previous self-reported studies about laughing at jokes and humour. Notably, conversational laughter frequently occurs following people's own verbal utterances rather than following deliberate humour, suggesting that conversational laughter is a voluntary communicative act that mediates the meaning of the preceding utterance and regulates the flow of interaction (Todt & Vettin, 2005; Vettin & Todt, 2004).

Similar to the functional distinctions of smiles, based on the recruitment of facial muscle units, it could occur spontaneously as a genuine ‘Duchenne display’ or under voluntary control as a posed ‘Non-Duchenne display’ (Ekman et al., 1990; Wild et al., 2003). Researchers, therefore, suggested laughter can be distinguished by whether it is the result of ‘Duchenne display’ or not, in other words, the way how it is elicited and under volitional control or not (Gervais & Wilson, 2005). Laughter can be either driven by external stimuli, such as ticking or humour, which is strongly linked to emotional arousal (genuine, spontaneous, involuntary laughter), or it can be a more controlled and communicative act, which is often used as a social signal during conversation (posed, deliberate, voluntary laughter) (Gervais and Wilson, 2005; Wild et al., 2003).

Indeed, human laughter is a social behaviour highly influenced by social contexts (Scott et al., 2014). It is not merely a spontaneous emotional vocalisation of joy and amusement, more importantly, it is a communicative signal that carries various social functions, such as punctuating speech, showing liking, agreement and affiliation in conversation (Provine, 1993; Vettin & Todt, 2004). As a social signal, the use of laughter in interactions is crucial for us to establish and maintain social bonds and relationships (Scott et al., 2014). Furthermore, the deep evolutionary root of laughter led to the proposal that laughter promotes group cohesion and social bonding, as well as builds rapport in human interaction (R. I. M. Dunbar et al., 2012; R. Dunbar & Mehu, 2008; Gray et al., 2015; Manninen et al., 2017).

1.2 The difference between genuine laughter and posed laughter

Although genuine and posed laughter are both salient social signals, they are distinct from each other: they are acoustically distinct and therefore play different roles in the communication of emotional and social meaning, they rest on different production systems and recruit different neural pathways in perception.

1.2.1 Acoustic and perceptual profile

Genuine, spontaneous laughter and posed, communicative laughter is acoustically distinct from each other. Moreover, the difference in its acoustic features influences people's perceptual judgement of its affective properties (Bryant & Aktipis, 2014) manipulated the speed of laughter selected from conversations between female friends. When laughs were sped up, participants judged the laughter as more 'real', suggesting that the acoustic properties of conversational laughter would affect its perceptual judgement. Lavan et al. (2016) compared the acoustic profile of genuine (spontaneous, authentic) laughter in response to humour videos with posed (volitional, fake) laughter produced under full voluntary control. Genuine laughter has a higher pitch, longer duration, and different spectral characteristics in comparison with posed laughter (Lavan et al., 2016). Investigating the acoustic features of laughter stimuli generated in a similar approach, McGettigan et al. (2015) found the same profile with genuine, evoked laughter having significantly higher pitch measures than posed, emitted laughter. Furthermore, they found that acoustic features have an impact on people's perceived affective properties of laughter. Genuine laughter was perceived as significantly more emotionally and behavioural contagious (contagion), more exciting and intense (arousal), more positive (valence), and categorised as 'real' (authenticity) than volitional laughter (McGettigan et al., 2015). This finding illustrated the authenticity of laughter (involuntary or voluntary) is different in its acoustic and perceptual profiles. Moreover, the difference in its acoustic features influences people’s perceptual judgement of its affective properties.

Additionally, the authenticity of laughter also leads to processing differences in the communication of emotional and social meaning. Neves et al. (2017) investigated the relationship between people’s self-reported resonance with others’ emotions and their performance in detecting the authenticity and contagion of genuine (involuntary) and posed (voluntary) laughter. The results showed that people with higher traits levels of emotional contagion and empathy are generally better at discriminating the authenticity of laughter (Neves et al., 2017a). Additionally, their perceived contagion responses during laughter perception were associated with better authenticity discrimination. This finding further supports the socio-emotional determinants of laughter (Scott et al. , 2014).

1.2.2 Neural mechanism of production

Neuroimaging evidence demonstrates that the production of genuine (involuntary) and posed (voluntary) laughter involves distinct brain systems (Belyk & McGettigan, 2022; Wattendorf et al., 2013; Wild et al., 2003). Based mainly on studies of pathological laughter, Wild et al. (2003) proposed that the production of involuntary and voluntary laughter involved two partially independent neuronal pathways: involuntary laughter is generated through subcortical and brainstem structures, including the amygdala, thalamic/hypo- and subthalamic areas and the dorsal/tegmental brainstem, whereas the production of voluntary laughter and the inhabitation of involuntary laughter is controlled by lateral motor cortex regions. By applying a multifiber tractography investigation on diffusion magnetic resonance imaging (dMRI) data, Gerbella et al. (2020) further supported the existence of two distinct networks of the production of emotional (involuntary) laughter and conversational (voluntary) laughter. These two networks interact throughout the pre-supplementary motor area (pre-SMA) that is connected to both the anterior cingulate (ACC), which is associated with affective and emotional laughter, and the frontal operculum (FO; a lateral motor cortex region), which is most likely the neural basis of non-emotional and conversational laughter (Gerbella et al., 2020).

Using functional magnetic resonance imaging (fMRI), Wattendorf et al. (2013) compared the brain activation of the production of on-demand voluntary laughter with involuntary laughter elicited by tickling. Increased activation was found in the hypothalamic during tickling laughter which is in line with Wild et al.'s (2003) finding. Surprisingly, the sensorimotor networks, including frontal operculum, primary sensory-motor and premotor region activity consistently activated during the production of both voluntary and involuntary laughter (Wattendorf et al., 2013), which contradicts the abovementioned findings (Wild et al.'s 2003; Gerbella et al., 2021). Belyk and McGettigan (2022) argued that this somewhat surprising finding could be due to the inhibition of head movement caused by laughing during scanning. Since fMRI data quality is sensitive to head movement, therefore, participants were inevitably instructed to minimise their movement while they were laughing – no matter when producing tickling or on-demand voluntary laughter. Taking this into account, Wattendorf et al. (2013)'s results might not reflect the fact of the production of involuntary laughter and voluntary laughter.

In a recent study, Belyk & McGettigan (2022) using real-time magnetic resonance imaging (rtMRI), compared the vocal tract shapes of participants producing spontaneous (involuntary) laughter, voluntary laughter, and speaking 'ha-ha-ha' vowels. They found the vocal tract shapes (e.g., tongue shape and velum) of voluntary laughter are intermediate between spontaneous laughter and vowels, supporting 'a dual pathway hypothesis for the neural control of human volitional and spontaneous vocal behaviours' (Belyk & McGettigan, 2022, p.1).

Together, this evidence suggests that the double-disassociation of neural systems engaged in laughter production: posed, voluntary and communicative laughter is likely involved in the volitional speech motor network (Scott, 2021), while genuine, involuntary and spontaneous laughter may be controlled by the older involuntary vocalisation network on the basis of evolution (Scott et al., 2014, 2022).

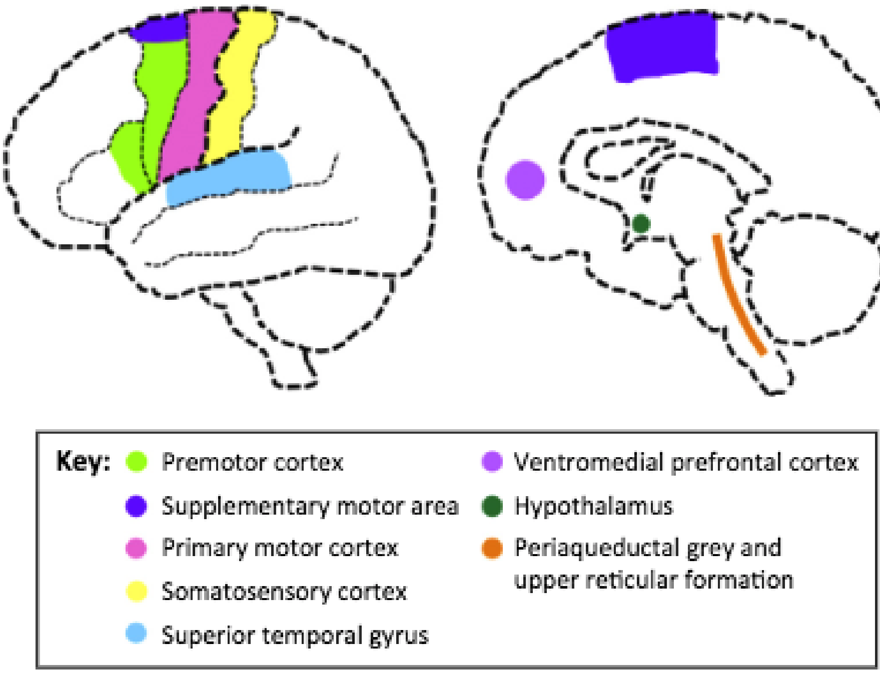


Figure 1.2 Posed (voluntary) and genuine (involuntary) laughter in the brain (Scott et al., 2014).

Note. The coordination of human laughter involves several brain regions, including the periaqueductal grey and the reticular formation, which receive inputs from the cortex, basal ganglia, and hypothalamus (Wild et al., 2003). In terms of laughter production, research has shown that the hypothalamus is more active during reactive laughter than during laughter under volitional control. Additionally, the motor and premotor cortices play a role in inhibiting the brainstem laughter centres and are more active during laughter suppression than during laughter production (Wattendorf et al., 2012). On the other hand, laughter perception involves the premotor cortex and supplementary motor area (Warren et al., 2006). Specifically, different brain regions are engaged in processing (genuine) involuntary and (posed) voluntary laughter, with auditory and mentalizing regions showing differential engagement (McGettigan et al., 2013).

1.2.3 Neural correlations of perception

In addition to the distinct mechanism of production, neural correlations of laughter perception not only involved in the high-order cognitive process, but also differ in regard to its authenticity (Lavan et al., 2017; McGettigan et al., 2015), and such difference further indicated the social signature of laughter (Scott et al., 2014).

When participants passively listened to positive nonverbal vocalisation (laughter and cheering) than negative nonverbal vocalisation (screams and disgust), Warren et al. (2006) found greater activation in the auditory-motor mirror network, including the premotor cortex and the pre-supplementary motor area (SMA), suggesting a fundamental mechanism for mirroring the emotional states of others during perceived positive nonverbal vocalisation (Warren et al., 2006).

Szameitat et al. (2010) used laughter produced by trained actors who imagined and recalled certain emotional states. They found higher activations in the anterior rostral medial frontal cortex (arMFC) during the perception of social-emotional (e.g., joyful and taunting) laughter, whereas stronger engagement in the right superior temporal gyrus (STG) during the processing of tickling laughter in neurotypical participants (Szameitat et al., 2010). In a follow-up brain connectivity study, Wildgruber et al. (2013) found that laughter with a higher degree of complex social meaning (social-emotional laughter vs tickling laughter) was associated with increases in connectivity between auditory association cortices, the right dorsolateral prefrontal cortex and brain areas associated with mentalising. These findings reflected the increasing demands on social cognition processes during perceiving laughter with social and emotional meaning (Wildgruber et al., 2013).

McGettigan et al. (2015) further investigated the neural responses whilst passively listening to laughter under different volitional control (genuine, involuntary laughter vs posed, voluntary laughter) in neurotypical adults. They found greater activity in superior temporal gyri (STG) when listening to genuine than posed laughter. Interestingly, greater activation has been found in the anterior medial prefrontal cortex (amPFC) and anterior cingulate cortex (ACC) when listening to posed laughter than genuine laughter. In addition, the performance of the participant’s authenticity judgement of laughter was strongly predicted by individual activation of amPFC area during the scan session. These findings suggest that participants recruit mentalising ability and attempt to determine others’ mental states when hearing others’ volitional and communicative laughter. In a follow-up study, Lavan et al. (2017) conducted parametric modulation to explore the relationship between neural correlates of passive perceiving genuine and posed laughter and participants' affective ratings of these two types of laughter. Similar to the previous study, they found the activation of amPFC showed negative linear correlations with authenticity and valence ratings of both types of laughter. Together, the involvement of mPFC suggests that laughter perception, especially the processing of posed and voluntary laughter, automatically engages people’s mentalising ability to understand and interpret the social-emotional meaning, such as others’ intentions and mental states behind the laughter.

1.3 Why does laughter matter to human beings?

As reviewed above, laughter is a universal social signal with a deep evolutionary root. Beyond the role of emotional expression of positive affect, human laughter predominately serves as a communicative tool in casual conversation. As a social behaviour, it is crucial for us to establish and maintain the social bond, promote group cohesion as well as build rapport in human interaction (R. I. M. Dunbar et al., 2012; Scott et al., 2014).

Laughter is often quoted as being the best medicine in life. Indeed, laughing benefits people's health in multiple ways, it helps to cope with stress and regulate negative emotions. A behavioural study found participants laughing in an individual setting rather than a social setting enhanced their positive affect and improved their mood (Neuhoff & Schaefer, 2002). Also, laughter contributes to better health conditions, such as improving immunity ability, pain tolerance and longevity (Martin, 2001). In a cross-sectional study, Hayashi et al. (2016) found the daily frequency of laughing is associated with a lower prevalence of cardiovascular diseases among Japanese elders (Hayashi et al., 2016). However, it is unlikely to conclude a causal effect of laughter on physical and mental health based on the above findings. By using positron emission tomography (PET), Manninen et al. (2017) revealed that laughter directly triggers the release of endogenous opioids in brain regions associated with reward processing and insular cortices, which links sensory experience and emotional valence. This evidence suggested an important neurochemical mechanism of laughter, including increasing positive mood and calmness in individuals and such that promotes intragroup affiliation and bonding in human interaction (R. I. M. Dunbar et al., 2012; Manninen et al., 2017)

1.4 Making sense of laughter in autism

Laughter is a universal nonverbal vocalization that is heavily influenced by social contexts and serves as a salient index for social well-being, playing a critical role in establishing and maintaining social relationships (Provine, 1993; Provine & Fischer, 1989; Scott et al., 2014, 2022; Vettin & Todt, 2004). While nonverbal communicative signals are important in social interaction, previous research has primarily focused on visual cues, such as eye contact, gesture, and facial expressions in autistic people (Golarai et al., 2006; Senju et al., 2009; Senju & Johnson, 2009; Trevisan et al., 2018). However, little attention has been given to the role of laughter behaviour in autism and their daily communication. Therefore, this thesis aims to address this gap in knowledge by investigating laughter as a nonverbal communicative signal in autistic adults who experience challenges in social communication.

The thesis seeks to deepen our understanding of laughter as a nonverbal communicative signal in the autistic people. Specifically, it aims to determine whether autistic people display unique patterns of laughter perception and production compared to non-autistic people within social communication by treating laughter as an experimental tool in following studies. Additionally, the thesis seeks to understand the neural mechanisms of laughter perception by using autism as an experimental manipulation in an fMRI study, given that previous fMRI studies have suggested the involvement of mentalizing in understanding the social ambiguity/attributing the mental states of other's laughter.

The primary motivation for this thesis is to shed light on the communicative function of laughter in the context of autism. In general, it aims to determine whether laughter can serve as a reliable indicator of social engagement and whether autistic adults display unique patterns of laughter behaviour compared to non-autistic individuals. By examining the relationship between laughter and autism, this thesis will contribute to a better understanding of the challenges faced by autistic people in social communication. By focusing on the communicative function of laughter in the context of autism, the thesis aims to improve our understanding of non-verbal social vocalization in autistic people, and to identify potential areas for intervention and support.

1.4.1 Autism, mentalising, and social communication

Autism spectrum disorder is a complex neurodevelopmental disorder that is primarily characterized by difficulties in verbal and nonverbal social communication, as well as the presence of repetitive behaviour and restricted interests (Association, 2013; U. Frith, 2001) Although autism is typically diagnosed during childhood, a significant number of individuals remain undiagnosed until later in life (U. Frith, 2001; Mandy et al., 2022). Moreover, autism is a lifelong condition that manifests itself in varying degrees of severity and can occur at all levels of cognitive ability (U. Frith, 2001). In addition, autism is frequently accompanied by a range of mental health conditions, including anxiety, depression, and other developmental disorders, such as attention-deficit/hyperactivity disorder (ADHD), and dyslexia (American Psychiatric Association, 2013).

One influential theory in explaining the social communication difficulties of autistic individuals is the ‘Theory of Mind’ (ToM) or ‘mentalising’ theory. It proposes that autistics experience difficulties in attributing mental states to oneself and to others and have difficulties in disassociating one’s own and other’s mental states (Baron-Cohen et al., 1985; U. Frith, 2001). These difficulties could lead to problems in representing alternative mental states, which refer to dysfunction in understanding others’ desires, beliefs and intentions. Extensive behavioural evidence supports this theory, with evidence from autistic children failed on explicit verbally instructed mentalising task (Sally-Anne false-belief task) at age 4 (Baron-Cohen et al., 1985; U. Frith, 2001) to evidence of spontaneous/implicit mentalising tasks showing that autistic individuals do not attribute mental states spontaneously even they are able to pass explicit mentalising tasks through compensation (Senju et al., 2009; White et al., 2014) (see Figure 1.3).

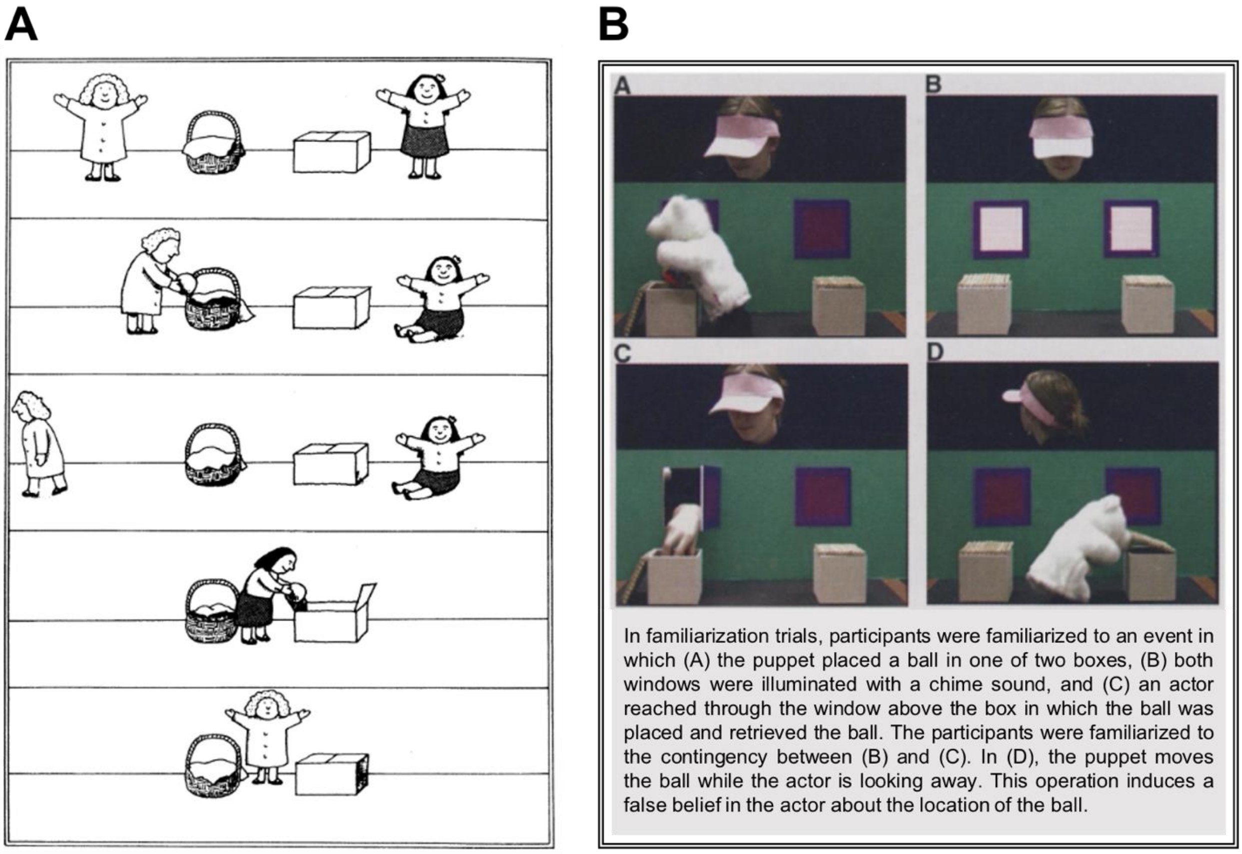


Figure 1.3 A) The Sally-Ann task (Frith, 2001); B) Spontaneous/implicit mentalising tasks (Senju et al., 2009)

Furthermore, the brain mentalising network mainly involves the prefrontal cortex (PFC), the inferior frontal gyrus (IFG), the temporo-parietal junction (TPJ), the posterior parietal cortex (PPC), the temporal pole, and the cingulate cortex (C. D. Frith & Frith, 2006; U. Frith, 2001; Monticelli et al., 2021)(see Figure 1.4). Emerging functional imaging evidence shows the activation in the 'mentalising' regions differs between autistic individuals and neurotypical controls by applied explicit and/or implicit mentalising tasks (C. D. Frith & Frith, 2006, 2008; U. Frith, 2001; Nijhof et al., 2018; Schneider et al., 2014; Senju et al., 2009). These findings not only suggest that autistic individuals are likely to experience dysfunctional mentalising ability, but also further support the hypothesis that their difficulties in social and communication in everyday life could be due to the dysfunctional connectivity of mentalising networks (C. D. Frith & Frith, 2006; U. Frith, 2001).

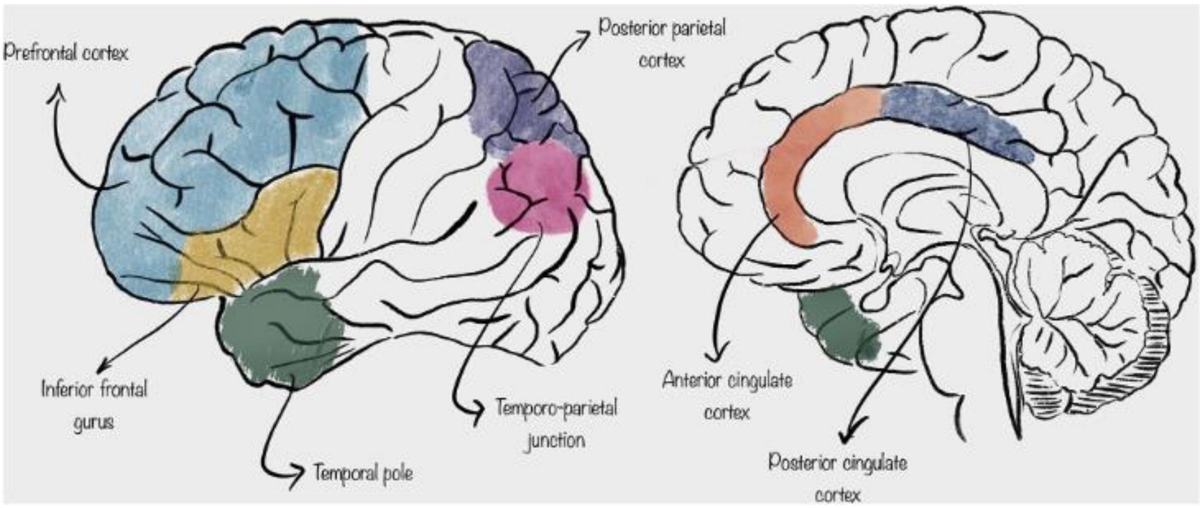


Figure 1.4 Mentalizing network in the brain (Monticelli et al., 2021)

As a consequence of dysfunctional mentalising ability, autistic individuals show impaired processing of non-verbal social-emotional communication(U. Frith, 2001). For instance, autistic children have evident difficulties in comprehending facial emotions in social situations, particularly when facial expressions are posed, despite recognising basic emotions in displays of cartoon faces (Dennis et al., 2000). In another study, autistic adults performed less well in discriminating between Duchenne (genuine) and non-Duchenne (posed) smiles than their neurotypical (NT) peers. And the ability to discriminate smiles is negatively correlated with the degree of social interaction impairment in autistic adults (Boraston et al., 2008). Importantly, the ability to distinguish a real from a posed smile is associated with the ability to understand and attribute other's mental state, as a posed smile can indicate the pretence of happiness or pleasure(Boraston et al., 2008). Struggling with mentalising, autistic adults unsurprisingly experience difficulty in distinguishing between genuine and posed smiles, and such difficulty in processing nonverbal social signals would conceivably lead to difficulties in everyday social interactions. Similar to smiles, laughter is a social behaviour, and it is frequently used as a social signal in our daily interactions. As reviewed above, the authenticity of laughter (genuine vs posed laughter) not only leads to processing differences in the communication of emotional and social meaning (Neves et al., 2017b), but also requires individuals to understand the meaning and intention behind the laughter (Lavan et al., 2017; McGettigan et al., 2015). However, autistic individuals may struggle to understand the social intentions of laughter in certain contexts due to mentalising difficulty.

However, some researchers have challenged the claim that autistic people lack a theory of mind, which suggests a failure to understand that others have a mind and that they themselves have a mind. Gernsbacher & Yergeau (2019) conducted a review of theory-of-mind tasks and found that the evidence fails to support the claim that autistic people are universally impaired in this area. They highlighted original findings that have failed to replicate and documented multiple instances in which theory-of-mind tasks fail to relate to each other and fail to account for the heterogeneity of autism characteristics, social interaction, and empathy. The author therefore concluded that the claim that autistic people lack a theory of mind is empirically questionable (Gernsbacher & Yergeau, 2019). However, one limitation of this paper is that it focuses primarily on the theory-of-mind hypothesis and does not explore other possible explanations for the social and communication difficulties experienced by autistic people. Additionally, the paper does not provide a comprehensive review of all the research on theory of mind and autism, but rather focuses on specific studies (e.g., explicit mentalizing tasks) and arguments.

Other influential cognitive theories of autism, such as Bayesian accounts (Bayesian and predictive coding theories of perception and cognition) and weak central coherence, propose that autism is characterized by differences in the way that individuals process and integrate information. According to Bayesian accounts, people use probabilistic reasoning to make sense of the world around them. This theory suggests that individuals continuously update their beliefs and expectations about the world based on incoming sensory information and prior knowledge. However, Bayesian priors are weaker in autism (E. Pellicano & Burr, 2012). A recent review collected and analysed 83 studies that tested the Bayesian theories of autism and find little support. The results were mixed, with some studies finding differences in the integration of priors and others finding no differences (Chrysaitis & Seriès, 2023) Weak central coherence, on the other hands, is a theory proposed by Frith and Happé in 1994, which suggests that autistic people tend to process information in a more local, detail-oriented manner, rather than taking a more global, holistic perspective. This can lead to difficulties with tasks that require integrating information from multiple sources or understanding the "big picture" of a situation, which can also lead to lead to difficulties in social communication and understanding (U. Frith & Happé, 1994) .

Alternative perspectives on autism are influenced by the neurodiversity paradigm, which emphasizes the unique cognitive diversity of individuals and the necessity to celebrate neurological differences rather than pathologizing them (Pellicano & den Houting, 2022). This paradigm challenges the conventional medical model of autism science, which views autism as a disorder of brain development and places limits on what we can know about it. The neurodiversity paradigm views autism as one form of variation within a diversity of minds and proposes a potential alternative to the medical model. It outlines how this approach can potentially help researchers respond to the limitations of the medical model, including an overfocus on deficits, an emphasis on the individual as opposed to their broader context, and a narrowness of perspective (E. Pellicano & Houting, 2022) The neurodiversity paradigm also brings attention to the "double empathy problem," which refers to a breakdown in mutual understanding between people, particularly between autistic and non-autistic individuals (Milton et al., 2022). Milton et al (2022) argued the idea that autism is primarily a deficit in social cognition or empathy and highlights the need for a mutual and interpersonal approach to understanding and supporting autistic people.

Understanding both the medical/cognitive models and social models associated with autism has important implications for various aspect of life, including social interactions, education, and employment. In this thesis, I will focus on both cognitive and social models in understanding the communicative function of laughter in the context of autism. Autistic people may experience laughter differently from non-autistic individuals, which could have implications for social bonding and emotional regulation. Failure to understand other's laughter could lead to difficulties for them in replicating and using laughter as a social signal in daily interactions. Since social and communication difficulties are important risk factors for mental health issues (e.g., social anxiety) (Pickard et al., 2017), their difficulties in forming relationships and maintaining social bonds with others could have long-term impacts on their mental health. Given the complexity of autism and the diversity of autistic experiences, a multi-disciplinary and multi-dimensional approach is needed to fully understand and support autistic people in this domain.

1.4.2 Limited laughter research in autism

Only a few studies have to date examined laughter in the autistic population, and most have been largely focused on autistic children.

Inconsistent evidence of a quantitative difference in laughter production between autistic and typical developing (TD) children has been found in observational studies. Snow, Hetzig, and Shapiro (1987) examined the occurrence of emotional expressions, in which laughter was present with other positive affective expressions (e.g., smiling), and they found a reduced frequency of positive expression in autistic children compared to their typical developing peers. Sheinkopf et al. (2000) investigated the vocal atypicality in autistic children, in which he defined laughter as the 'proportion of syllables where children were judged as laughing' (p. 349). The results indicated no significant difference in laughter ratios between autistic and typical developing children (Sheinkopf et al., 2000). Notably, these studies were originally focused on the other aspect of social communication in autistic children. Therefore, they A) lacked a clear definition of laughter; and B) they did not isolate laughter from other positive emotional expressions (Hudenko et al., 2009).

Further, two observational studies isolated laughter from other positive vocalisations and investigated humour and laughter in children with autism and Down Syndrome (DS). No quantitative differences have been found in these studies; however, qualitative differences exist in laughter production between children with autism and DS. James et al. (1994) reported no significant differences between the rate of laughter production among children with autism and those with Down Syndrome (James & Tager-Flusberg, 1994). Reddy et al. (2002) approached the question with detailed parental interviews and observation during play. Parental reports revealed no group difference in laughter frequency, however, the events that elicited laughter did. More specifically, while DS children laughed in response to seeing funny faces and socially inappropriate acts, significantly fewer autistic children laughed after such events. In addition, autistic children produced significantly more unshared laughter in the interactive situation than children with Down Syndrome. Furthermore, fewer autistic children were reported to join in others' laughter or elicit laughter from others by clowning or teasing, in the subsequent observation sessions, most autistic children were found paying no attention (neither looking up nor smiling) in response to parents' laughter (Reddy et al., 2002). The authors further attributed the lack of interest in laughter behaviour in autistic children to their difficulties in attention and emotion resonance.

Some studies have focused on the acoustic features of laughter produced by autistic children, and further support the existence of qualitative differences. Hudenko et al. (2009) investigated the laughter production of autistic children during social play. Their findings reveal no differences in the laugh duration or mean fundamental frequency (F0) values between autistic and typical-developing children. However, autistic children produced primarily 'voiced laughter', which is most often linked to the producer's positive internal state and affective state (Bachorowski et al., 2001; Smoski & Bachorowski, 2003), but display relatively little 'unvoiced laughter', which typical-developing children appear to rely on heavily during social interactions, with its usage increasing through development and modulated by social circumstances (Bachorowski et al., 2001; Hudenko et al., 2009; Smoski & Bachorowski, 2003). To examine whether the 'voiced' laughter produced by autistic children is associated with positive and affective feelings, a follow-up study used the same laughter as stimuli to explore whether neurotypical adults who were naïve listeners could distinguish between laughter produced by typical developing children and autistic children, and whether they showed a preference for laughter in one of the two groups (Hudenko & Magenheimer, 2012). Results showed that neurotypical adults rated the laughs of autistic children more positively than they rated the laughs of typical developing children. This finding could be taken to indicate that the ‘voiced laughter’ produced by autistic children is less socially motivated to influence or manipulate others but rather a genuine expression of positive affect. In contrast, the laughter produced by typical developing children involved lower arousal, and less genuine expression in response to social cues, such as using laughter for social affiliation and negotiation (Hudenko & Magenheimer, 2012).

Besides the qualitative difference in laughter production exits between autistic children and their TD, and DS peers, a few studies investigated laughter perception in autistic individuals and found the existence of different processing patterns. Helt & Fein (2016) found typical developing children rated Tom and Jerry cartoons as more enjoyable when a laugh track is superimposed upon the cartoon than in the absence of any laughter. However, autistic children rated the laughter-track cartoon less enjoyable than their TD peers; and they found the presence of laughter decreased their enjoyment of the cartoon. Besides an opposite tendency of enjoyment ratings in the two groups, Helt and colleagues also found the observed laughter and smiles in the two groups are in line with self-reported enjoyment: TD children laughed more when watching the cartoon with a laughter track than autistic children did (Helt & Fein, 2016a). However, more recent evidence suggests that autistic children do find laughter contagious but are more sensitive to the task context and familiarity of the laughter than NT controls (Helt et al., 2020). Sumiya and colleagues (2020) manipulated laughter as a social-reward cue after presenting visual jokes. The punchlines of jokes were also manipulated in two ways: either the participant uttered the punchline of the joke, or the participant listened to the punchline read aloud by the computer. TD and autistic adults were required to rate their subjective pleasure of jokes stimuli when the jokes were either present without laughter or followed with single or group laughter.

Both NT and autistic adults found greater laughter increment contributed to the greater subjective pleasure of jokes stimuli (Group laughter > Single laughter > No laughter). Although there was no group difference in perceived pleasure in No laughter and Single laughter conditions, a significant difference was found in Group laughter conditions among autism and TD groups. These findings suggest that the laughter increment effect on the perceived pleasure of jokes was lesser in the autism group (Sumiya et al., 2020).

In summary, research is scarce in investigating laughter production and perception in the autistic population, especially in autistic adults. Although previous studies found a different pattern of laughter production and perception between autistic individuals and TD, DS controls. However, it generally lacked a precise focus on laughter as a social behaviour and a well-grounded design to explore the critical role of laughter in social communication. Due to the limited number of studies, more research is needed to afford a more rounded overview of laughter behaviour and its underlying neural mechanism in autistic adults, particularly focusing on how they differ between genuine and posed laughter. Therefore, the aim of this thesis is to extend our current understanding of laughter as a social communicative signal from non-autistic adults to autistic adults.

1.5 Conclusion

In this chapter, I briefly introduced the evolutionary root of laughter in mammals and human beings. I summarised the findings about the communicative roles of laughter in human interaction and therefore stated the fact that laughter is a social behaviour. Based on that, I further reviewed previous findings of the difference between genuine and posed laughter in acoustic profile, perception, and production, in which I further indicated the social-emotional signature of laughter in everyday social communication. Then I reviewed the previous laughter research on the autistic population and pointed out the necessity of importing new approaches to investigate laughter behaviour in this domain. Therefore, the focus of the current thesis will be on autistic and non-autistic adults, I will implement questionnaire, behavioural tastings and neuroimaging to investigate the daily experience, production, perception and underlying neurocognitive mechanism of laughter and its function in social interaction.

In the next chapter (chapter 2), I will first investigate people's self-reported laughter experiences in everyday life. I will employ a laughter questionnaire to investigate the difference in laughter behaviour and experience on four components: Liking, Frequency, Usage and Understanding, between autistic and non-autistic adults through both in-lab and online datasets.

In chapter 3, I will focus on laughter production between autistic and non-autistic adults. I will implement a multi-level dyadic study of non-autistic and autistic pairs in a video recording and motion-capture setting to look at laughter production in friend and stranger pairs in different types of social situations (shared conversation vs shared experience of watching funny videos).

In the following chapters, I will switch the angle to laughter processing between autistic and non-autistic adults. In chapter 4, I will utilise an explicit rating task to investigate differences in the perceptual affective properties of laughter between autistic and non-autistic adults.

In chapter 5, I will introduce a series of implicit laughter processing tasks based on the novel paradigm I designed, showing the addition of laughter modulated the funniness of pun jokes. I will extend the paradigm by replacing the jokes with a variety of humour stimuli (e.g., burp sounds, slapstick videos) to replicate our findings in the non-autistic and autistic populations.

In chapter 6, I will apply a subsequent fMRI study to deepen our findings from a behavioural level to the brain mechanisms, highlighting the engagement of the mPFC and mentalising in the implicit processing of laughter in the non-autistic population, but not in autistic adults, and also reduced discrimination between these laughter types in autistic adults.

In the last chapter (chapter 7), I will summarise all the findings in this thesis and discuss current research limitations, as well as how these current results relate to previous studies and benefit future research.

Chapter 2. Laughter Experience in Everyday Life: A Questionnaire Study

2.1 Abstract

Laughter is a universal emotional expression and an important communicative tool in social interactions and yet, few studies have investigated laughter in autism. In this study, we aimed to investigate the difference in daily laughter experience between autistic adults with IQ in normal range and their non-autistic peers. A laughter questionnaire was used to explore self-reported understanding, usage, liking and frequency of laughter behaviour. Compared to non-autistic adults, autistic adults reported that they laugh less, enjoy laughter less and find it more difficult to understand the social meaning of other people's laughter. However, autistic adults reported that they laugh on purpose as often as non-autistic (NA) adults, using intentional laughter to mediate social contexts. These results were consistent across data collected in-lab (NA n=67; NA subgroup n=30; Autism n=28) and online (NA n=52; NA subgroup n=31; Autism n=35). In summary, there are differences between autistic and non-autistic adults in the personal experience of laughter behaviour. As autistic adults reported that they struggle to understand the social meaning of others' laughter, this may result in using and enjoying laughter less in everyday life and may indicate that autistic adults use different strategies to understand and produce laughter in social interactions.

2.2 Introduction

As reviewed in Chapter 1, laughter is a universal non-verbal expression of emotion in human interactions (Ruch & Ekman, 2001; Sauter et al., 2010). Laughter acts as a communicative tool and conveys social functions, such as showing friendliness, affiliation, agreement with others, mediating the meaning of utterances, and regulating the flow of conversation (Vettin & Todt, 2004). Laughter, therefore, serves as a social signal mediated by social contexts (Scott et al., 2014). The deep evolutionary roots of laughter have led to the proposal that laughter promotes group cohesion and social bonding, as well as building rapport in human interaction (R. I. M. Dunbar et al., 2012).

Laughter not only influences our real-life social well-being; it is also quoted as being the "best medicine in life". Indeed, laughter benefits our health in multiple ways. Berk et al. (1989) compared the pre- and post-blood samples by exposing participants to comedy that elicited their laughter and found a significant change in hormonal response compared to controls. Reductions in stress hormones indicated that laughter could enhance our mood and provide a buffer against stress (Neuhoff & Schaefer, 2002). By reducing stress and enhancing mood, laughter contributes to improved health, such as improving immunity ability, pain tolerance and longevity (Martin, 2001). For instance, a cross-sectional study found that the daily frequency of laughter is associated with a lower prevalence of cardiovascular diseases among Japanese elders (Hayashi et al., 2016). Although the above findings have methodological issues (e.g., using a correlational research design) that make it hard to infer a causal effect of laughter on physical and mental health, Manninen et al. (2017) used PET (Positron Emission Tomography) and revealed that laughter directly triggers the release of endogenous opioids in brain regions associated with reward processing and insular cortices which links sensory experience and emotional valence. This aforementioned evidence suggests an important neurochemical mechanism of laughter, including increasing positive mood and calmness, as well as promoting intragroup affiliation and bonding (R. I. M. Dunbar et al., 2012; Manninen et al., 2017).

Despite laughter being crucial in establishing and maintaining social relationships, only a small number of questionnaire studies have focused on investigating individual laughter experiences. Some of the questionnaires failed to measure laughter isolated from humour (e.g., SHRQ; Martin & Lefcourt, 1984; CHS; Martin & Lefcourt, 1983) (Martin & Lefcourt, 1983, 1984), and some of the questionnaires measure abnormal and unusual laughter preferences (e.g., PhoPhiKat-45; Ruch & Proyer, 2009 personal) (Ruch & Proyer, 2009), including personal fear and joy of being laughed at (gelotophobia and gelotophilia respectively) and personal joy of laughter at others (katagelaticism). To date, only one study developed a laughter questionnaire which focused on people's self-reported healthy laughter experiences in everyday life (Muller et al., in prep). In total, 838 participants completed the 30-item questionnaire and a principal component analysis resulted in the extraction of four components, including how often people produce laughter (Frequency, 'I laugh a lot'), their understanding of other's laughter (Understanding, 'I understand the laughter of others'), their social usage of laughter (Usage, 'I use laughter for its positive social effects'), and their general feelings towards laughter (Liking, 'I like laughter'). These four components measure people's daily laughter behaviour in both production level (Frequency and Usage) and perception level (Understanding and mostly Liking).

Unfortunately, there is scarce laughter research in the autistic population. Limited studies found a different pattern of laughter production and perception between autistic people and their typical developing peers or peers with Down Syndrome (e.g., (Auburn & Pollock, 2013; Bauminger et al., 2008; Helt & Fein, 2016a; Hudenko et al., 2009; Reddy et al., 2002). In general, previous studies found autistic children join in others' laughter less during social play, and they also show reduced contagious laughter while watching funny cartoons alongside others (Helt et al., 2020; Helt & Fein, 2016a; Reddy et al., 2002). In addition, autistic children rarely laugh in response to social events or use laughter as a social signal (Auburn & Pollock, 2013; Bauminger et al., 2008; Helt & Fein, 2016a; Hudenko et al., 2009; Reddy et al., 2002).

Besides the differences in the pattern of laughter production, acoustic differences in laughter production have been found: autistic children produce primarily 'voiced' laughter, which is most often linked to the producer's positive internal state and affective state (Smoski & Bachorowski, 2003), but display relatively little 'unvoiced laughter', which non-autistic children appear to rely on heavily during social interactions, with its usage increasing through development and modulated by social circumstances (Bachorowski et al., 2001; Hudenko et al., 2009).

Since laughter is a salient index for social well-being, it is worth investigating laughter behaviour in autistic people as they are known to have difficulties in social communication (U. Frith, 2001). Besides focusing on observation/lab data, it is helpful to illustrate the picture of laughter behaviour and experience based on self-report data. If a mismatch would be found between existing observation/lab data and self-report data, it might indicate that 1) different people might laugh more or less in experimental contexts (e.g., audience effect) so self-report is a more naturalistic and accurate approach in measuring laughter behaviour, or 2) autistic people lacks a good insight into their own social communication behaviour and cognition. More recently, the focus of autism research has shifted, with increased attention to the first-person experience of autistic people, which highlights the importance of understanding autistic adulthood and thus supporting flourishing autistic lives (E. Pellicano et al., 2022; L. Pellicano et al., 2018). So far, no research has used self-report questionnaires to examine the first-person experience of laughter in autistic adults. Therefore, it is important to understand the role of laughter in everyday life among autistic adults, not only promoting the autistic voice in this area but also providing a better understanding of the unique profile of nonverbal social communication in autistic adults.

Therefore, this study aims to provide a detailed picture of how autistic people experience (e.g., perceive, understand and use) laughter in everyday life. Both autistic and non-autistic adults (comparable for age, gender and IQ) completed a 30-item laughter questionnaire via an in-lab experiment and a supplementary online experimental setting. The supplementary online experiment was conducted three years after the in-lab experiment during COVID to replicate the findings. Based on the abovementioned evidence of different patterns of laughter production and perception between autistic people and their peers, we hypothesised that self-reported laughter in both production level (Frequency and Usage) and perception level (Understanding and mostly Liking) would differ between autistic adults and non-autistic adults. Furthermore, this difference would be consistent in both in-lab groups and online groups.

2.3 Method

2.3.1 In-lab participants

In total, 28 autistic adults and 67 non-autistic (NA) adults, who were native English speakers, were recruited from the Autism@ICN participant database and UCL SONA subject system for an in-lab experiment.

All 28 autistic participants had received a diagnosis of Autism Spectrum Disorder (n = 12) or Asperger syndrome (n = 16) from a qualified clinician. The Autism Diagnostic Observation Schedule (ADOS-2, module 4; Hus & Lord, 2014) was used to verify the diagnosis of 26 autistic participants. Of these, eighteen of them either met the criteria for autism (n = 13) or autism spectrum classification (n = 5). The remaining eight scored below the threshold but were retained within the group: five of them reported an AQ score above the 32-cut-off point and one scored 31, which are considered clinically significant levels of autistic traits; additionally, they all reported significant social difficulties in everyday life. Furthermore, scoring below the threshold on the ADOS is not unusual; the ADOS has been shown to be less sensitive in autistic people with IQ in the normal range (Kamp-Becker et al., 2013).

NA participants were over-recruited on purpose to provide as close a match as possible of a subgroup to the autistic group. The full NA group was younger and females were relatively overrepresented. Exclusion criteria were therefore to exclude females aged below 31 (n = 26) and males aged below 25 (n = 11). Thus 30 NA adults remained in the NA subgroup for further group comparisons. The groups were comparable on sex ($\chi^2(1) = .646$, $p = .421$), age ($t(56) = .722$, $p = .473$), verbal ($t(56) = -.803$, $p = .426$), and full-scale ($t(56) = -.631$, $p = .531$) IQ, as measured by the Wechsler Adult Intelligence Scale (WAIS-III/IV; Wechsler, 2008); 18 NAs completed 4 subtests of WAIS-IV (Block Design; Vocabulary; Matrix Reasoning; Similarities), 1 autistic adult completed the WAIS-IV, and all others completed the WAIS-III. As expected, the groups differed in their self-report of autistic traits, measured by the Autism-Spectrum Quotient (AQ; (Baron-Cohen et al., 2001), ($t(56) = 6.876$, $p < .001$). Full details of the two groups are given in Table 2-1.

Table 2-1 Background details of the participant groups

	NA	**NA Subgroup**	**Autism**
N (male: female)	67 (33:34)	30 (22:8)	28 (23:5)
Age (years)	27.642 (6.552)	33.000 (5.693)	34.143 (6.364)
Verbal IQ	120.119 (14.523)	118.233 (12.724)	115.214 (15.847)
Full Scale IQ	117.881(15.326)	116.533 (14.827)	113.929 (16.615)
AQ	14.955 (7.951)	16.067 (7.719)	32.357 (10.228)
ADOS total [a]	-	-	8.962 (4.142)
-communication subscale	-	-	2.692 (1.715)
- social subscale	-	-	6.269 (3.027)

Note. Values are given as mean (standard deviation), except when otherwise stated. NA = Non-autistic; AQ = autism-spectrum quotient. [a] Two autistic participants did not complete the ADOS.

2.3.2 Online participants

Under COVID-19 testing restrictions, 52 NA adults (37 females; average age = 24.072, *SD* = 4.423) and 37 autistic adults were recruited via Prolific (www.prolific.co) for an online experiment. NA adults were over-recruited to enable an NA subgroup and to match to the autistic group. The exclusion criteria were set up based on participants' ages and their performance on the verbal task; males and females aged below 28 and adults with a verbal task score below 60 were excluded from the NA group ($n = 21$). Two autistic participants were excluded from the autism group because they self-identified as autistic without receiving any clinical diagnosis and their AQ-10 (Allison et al., 2012) score was below the cut-off point of 6.

The remaining groups were comparable on sex ($\chi^2(1) = .649$, $p = .421$), age ($t(62.312) = -1.017$, $p = .313$), verbal ($t(64) = -.809$, $p = .422$), and non-verbal ($t(64) = .047$, $p = .963$) abilities, as measured by the Spot-the-Word test (StWt; Baddeley et al., 1993) (Baddeley et al., 1993)and the Matrix Reasoning Item Bank (MaRs-IB; (Chierchia et al., 2019) respectively. As expected, the groups differed in their self-report of autistic traits, measured by the Autism-Spectrum Quotient 10-item (AQ-10; Baron-Cohen, , 2001) (Allison et al., 2012), ($t(59.203) = -8.801$, $p < .001$). Full details of the two groups are given in Table 2-2.

Table 2-2 Background details of the participant groups

	NA	NA Subgroup	Autism
N (male: female)	52(15:37)	31(7:24)	35 (11:24)
Age (years)	24.072(4.422)	25.929 (4.562)	27.269 (6.106)
Verbal ability	69.673(10.382)	74.548 (9.287)	76.714 (12.075)
Non-verbal ability	59.365(18.264)	62.484 (18.156)	62.257 (21.056)
AQ-10 [a]	3.308(1.710)	3.032 (1.538)	7.286 (2.346)

Note. Values are given as mean (standard deviation). NA = Non-autistic; AQ = autism-spectrum quotient. [a] Two autistic participants did not complete the AQ-10.

2.3.3 Materials, design and procedure

2.3.3.1 Laughter questionnaire

The 30-item Laughter Questionnaire was a self-report questionnaire designed to explore people's experiences of laughter in daily life (Muller et al., In Prep). It originated from an item pool with over 100 items regarding people's experiences of their laughter production and perception, and the final 30 items were selected from people's responses to the original items after conducting principal components analyses (PCAs). In order to derive principal components from the 30 items, a further group of 838 English-speaking participants (304 females; Mean Age = 39.12 years, SD Age = 11.97 years) completed the final version of the laughter questionnaire. The final version of the 30-item laughter questionnaire consisted of four components: 'Frequency', 'Understanding', 'Usage' and 'Liking'. The four components describe people's personal experience of laughter production and perception. In terms of laughter production, 'Frequency' (7 items) measures how often people produce laughter in daily life, and 'Usage' (5 items) measures people's positive usage of laughter, particularly in using laughter as a social signal to mediate social context. In terms of laughter perception, 'Understanding' (9 items) measures people's understanding of the social meaning of other's laughter; and 'Liking' (8 items) measures people's general feelings towards laughter and their emotional valence of processing other's laughter. One item ('Hearing people faking laughter irritates me') did not load on any of the four components but was kept in the questionnaire. See Table 2-3 for the details of the items. See Appendix 2b for further information.

Table 2-3 Four extracted principal components and the items (Muller et al., In prep)

Frequency
1. I rarely laugh when I am on my own.
2. I have a subdued laugh.
3. I find things funny, but I rarely laugh out loud.
4. I laugh less often than most people I know.
5. I laugh more than most people I know.
6. I rarely break into uncontrollable laughter.
7. If I find something funny, I often laugh out loud.
Understanding
1. I can tell when people are laughing because they want something from me.
2. I can tell when someone is laughing to stop me getting angry at them.
3. I can tell when someone is deliberately laughing to pretend that they are amused.
4. I can never tell if someone is deliberately laughing to pretend that they are amused.
5. I can never tell if someone is laughing because they want something from me.
6. I can never tell if someone is laughing to stop me getting angry with them.
7. Sometimes I find it difficult to tell when someone is laughing nastily.
8. Sometimes I find it difficult to tell when someone is laughing just to be polite.
9. I can always tell if someone is laughing at or with me.
Usage
1. I often laugh deliberately to show that I like someone.
2. I laugh more when I want people to like me.
3. Sometimes I laugh to stop other people from getting angry with me.
4. I sometimes laugh to avoid expressing sadness.
5. I often laugh to avoid expressing frustration.
Liking
1. Hearing laughter makes me nervous.
2. I dislike people who laugh a lot.
3. When I am upset, hearing someone laugh makes me feel better.
4. If I am happy, hearing someone laugh makes me even happier.
5. I enjoy the sound of people laughing.
6. A friend's laughter is always good to hear.
7. Laughter has a positive influence on interactions with people.
8. I find laughter an important part of intimate relationships.

Note. The item ‘Hearing people faking laughter irritates me’ did not contribute to either of the four components and is therefore not shown in this table.

2.3.3.2 Testing procedure

The 30-item laughter questionnaire was presented within a longer testing battery in both in-lab and online experiments. Participants were given printed questionnaires for in-lab testing, whilst the items were presented in random order on Gorilla Experiment Builder (https://gorilla.sc/) for online testing. In both in-lab and online testing, participants were asked to state the extent of their agreement with each item on a Likert-type scale ranging from 1 ('strongly disagree') to 7 ('strongly agree'). Informed written consent was obtained before both online and in-lab testing sessions, and the project received approval from the UCL Research Ethics Committee.

2.4 Results

Data were analysed in IBM SPSS Statistics (version 27; www.ibm.com/uk-en/products/spss-statistics) and RStudio Team (2020). Reported *p* values are two-tailed. Prior to statistical tests, data was plotted to investigate its distribution and identify outliers.

2.4.1 In-lab dataset

Firstly, the missing data were examined in raw questionnaire data. In total, eight responses (0.2%) were missing from the complete dataset; further, the Little's Missing Completely at Random test (MCAR) was used, $\chi^2(113) = 138.254$, $p = .053$, and it indicated that the data were missing completely at random. Therefore, pairwise deletion was used to treat the missing data; each missing data point was excluded from the mean calculations of the composite scores for each component.

Secondly, negatively phrased items were reversed and the composite scores for each component were calculated by averaging the score of the contributing items, resulting in a Liking, Understanding, Usage and Frequency score for each participant, ranging from 1 to 7. For example, for the component Understanding, the items were coded in a way that a higher composite score corresponds with a better understanding of other people's laughter. In the same way, the other three components were coded: higher composite scores correspond to higher Frequency of laughter, more Liking of laughter, and more Use of laughter.

The distribution of each composite score among the NA and autism groups was assessed for its normality. The Shapiro-Wilk test indicated that the data of the NA group was normally distributed on Frequency, $W(67) = .972$, $p = .137$, Understanding, $W(67) = .982$, $p = .457$, and Usage, $W(67) = .975$, $p = .200$; and the data of the autism group was normally distributed on all four components: Frequency, $W(28) = .972$, $p = .647$, Understanding, $W(28) = .964$, $p = .421$, Usage, $W(28) = .972$, $p = .622$ and Liking, $W(28) = .940$, $p = .108$. Although one component, Liking, was not normally distributed in the NA group, $W(67) = .929$, $p < .001$, the Q-Q plot suggested that the data was approximately normally distributed. In addition, one potential outlier was detected on the Liking component in each group. As these two outliers did not alter statistical outcomes, all data were included in further analyses. See Figure 2.3 in Appendix 2A for details.

An independent samples t-test indicated that there was a significant difference between the autism and NA groups for Frequency, $t(93) = 3.083$, $p < .01$, Understanding, $t(93) = 7.372$, $p < .001$, and Liking, $t(93) = 5.307$, $p < .001$. However, no significant difference was found between the groups on Usage, $t(93) = -.046$, $p = .964$. To check that the pattern of differences between the autism and NA groups were not due to demographic differences between the autism group and the full NA group, we repeated the analysis with the NA subgroup, and the results showed a similar pattern. A significant difference was found for Frequency, $t(56) = 2.761$, $p < .01$, Understanding, $t(56) = 5.888$, $p < .001$, and Liking, $t(56) = 3.989$, $p < .001$, but not on Usage, $t(56) = -.072$, $p = .943$. See Figure 2.1.

Observing the means, these significant differences arose from the NA adults reporting laughing more frequently and liking laughter more than autistic adults, as well as being better at understanding others' laughter than autistic adults. However, NA and autistic adults reported that they used laughter positively to the same degree. (see Table 2-4 for means and standard deviations)

Table 2-4 Descriptive statistics for the four components from the in-lab sample

	NA *N* = 67	**NA subgroup** *N* = 30	**Autism** *N* = 28
Frequency	4.920 (1.092)	4.974 (1.031)	4.106 (1.351)
Understanding	5.048 (0.990)	5.019 (1.073)	3.376 (1.050)
Usage	3.743 (1.355)	3.733 (1.188)	3.757 (1.336)
Liking	5.993 (0.737)	5.888 (0.638)	5.002 (1.022)

Note: Values are given as mean (standard deviation). NA = Non-autistic.

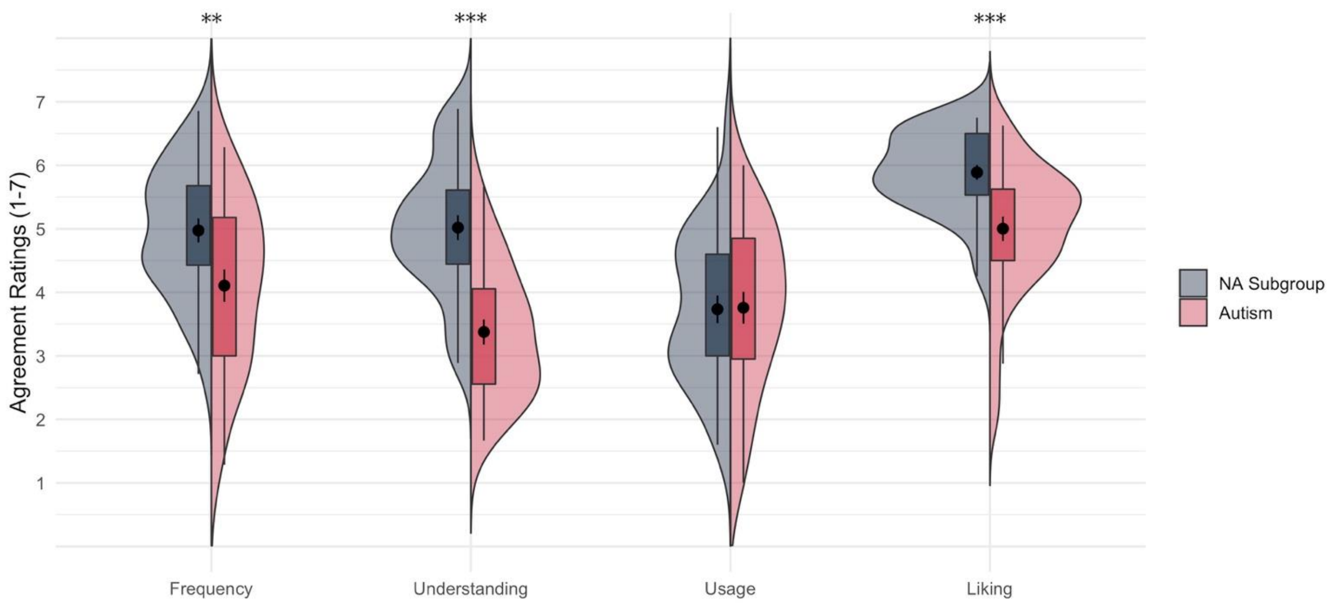


Figure 2.1 Average ratings for agreement on four components between the Non-autistic subgroup and Autistic group from the in-lab dataset

Note. Significance stars are the same for NA vs Autism, and for NA subgroup vs Autism on each component. NA = Non-autistic. Dot with short line = mean ± 1SE. Significance code: $p < .01$ = **; $p < .001$ = *** .

2.4.2 Online dataset

The composite scores of the components (Frequency; Understanding; Usage and Liking) were calculated for each participant based on the method above.

The distribution of the composite score of each component among the NA and autism groups was assessed for its normality. The Shapiro-Wilk test indicated that the data of the NA group was normally distributed on Frequency, $W(52) = .979$, $p = .492$, and Understanding, $W(52) = .977$, $p = .420$; and the data of the autism group was normally distributed on Frequency, $W(35) = .943$, $p = .071$, Understanding, $W(35) = .973$, $p = .543$, and Liking, $W(35) = .974$, $p = .559$. Although the NT group was not normally distributed on two components, Liking, $W(52) = .947$, $p = .021$, and Usage, $W(52) = .953$, $p = .040$, and the autism group was not normally distributed on Usage, $W(35) = .924$, $p = .019$, the Q-Q plot suggested that the data was approximately normally distributed. In addition, two potential outliers were detected in the Usage component in the autism group. As these two outliers did not alter statistical outcomes in the results of the matched groups, therefore, all data were included in further analyses. See Figure 2.4 in Appendix 2A for details.

Independent samples t-tests indicated that there was a significant difference between the autism and NA groups on the Frequency, $t(85) = 3.971$, $p < .001$, Understanding, $t(58.831) = 5.688$, $p < .001$, and Liking composite scales, $t(54.942) = 6.328$, $p < .001$. However, no significant difference between the groups was found for Usage, $t(85) = -1.258$, $p = .212$. To check that any differences between the autism and NA groups were not due to demographic differences between the autism group and the full NA group, we repeated the analysis with the NA subgroup, and the results showed a similar pattern in all components. A significant difference was found on the Frequency, $t(64) = 3.689$, $p < .001$, Understanding, $t(60.488) = 5.298$, $p < .001$, and Liking composite scores, $t(54.288) = 6.820$, $p < .001$, but there was no significant difference on Usage, $t(64) = - .974$, $p = .334$. See Figure 2.2.

As with the in-lab results above, observation of the means revealed that NA adults report that they laugh more and they like laughter more than autistic adults, and are also better at understanding others' laughter than autistic adults. However, NA and autistic adults reported that they use laughter for its positive effects to the same degree. (see Table 2-5 for means and standard deviations)

At the beginning of the study, participants were asked to complete the 10-item Positive Affect Schedule (PAS-10; Watson, Clark, & Tellegen, 1988), which served as a baseline measure of emotion and mood. They were instructed to 'indicate to what extent you feel this way right now, that is, at the present moment'. A significant difference has been found in the baseline emotion between the NA subgroup (M = 33.742, SD = 8.780) and the autism group (M = 28.086, SD = 7.913), $t(64) = 2.756$, $p = .008 < .01$. We conducted additional ANCOVA analyses by controlling the baseline mood as covariate in the comparison between NA subgroup and autism group. The covariant, baseline mood, was significantly related to the Frequency, $F(1, 63) = 9.416$, p = .003 < .01. In terms of group difference on components, a significant difference was found on the Frequency, $F(1, 63) = 7.346$, $p = .009 < .01$, Understanding, $F(1, 63) = 23.984$, $p < .001$, and Liking composite scores, $F(1, 63) = 35.358$, $p < .001$, but there was no significant difference on Usage, $F(1, 63) = .814$, $p = .370$, after controlling for baseline mood.

A further ANCOVA analysis was conducted on NA group and autism group by controlling the baseline mood as covariate. Again, the covariant, baseline mood, was significantly related to the Frequency, $F(1, 86) = 10.093$, p = .002 < .01. Same as the group difference detected above, a significant difference was found on the Frequency, $F(1, 86) = 8.427$, $p = .005 < .01$, Understanding, $F(1, 86) = 32.640$, $p < .001$, and Liking composite scores, $F(1, 86) = 30.373$, $p < .001$, but there was no significant difference on Usage, $F(1, 86) = .389$, $p = .535$, between NA group and autism group after controlling for baseline mood.

Table 2-5 Descriptive statistics for the four components from the online sample

	NA *N* = 52	**NA subgroup** *N* = 31	**Autism** *N* = 35
Frequency	4.772 (1.251)	4.876 (1.293)	3.592 (1.508)
Understanding	4.812 (0.812)	4.792 (0.747)	3.587 (1.086)
Usage	3.935 (1.061)	3.981 (0.953)	4.240 (1.181)
Liking	5.858 (0.757)	5.984 (0.616)	4.496 (1.112)

Note: Values are given as mean (standard deviation). NA = Non-autistic.

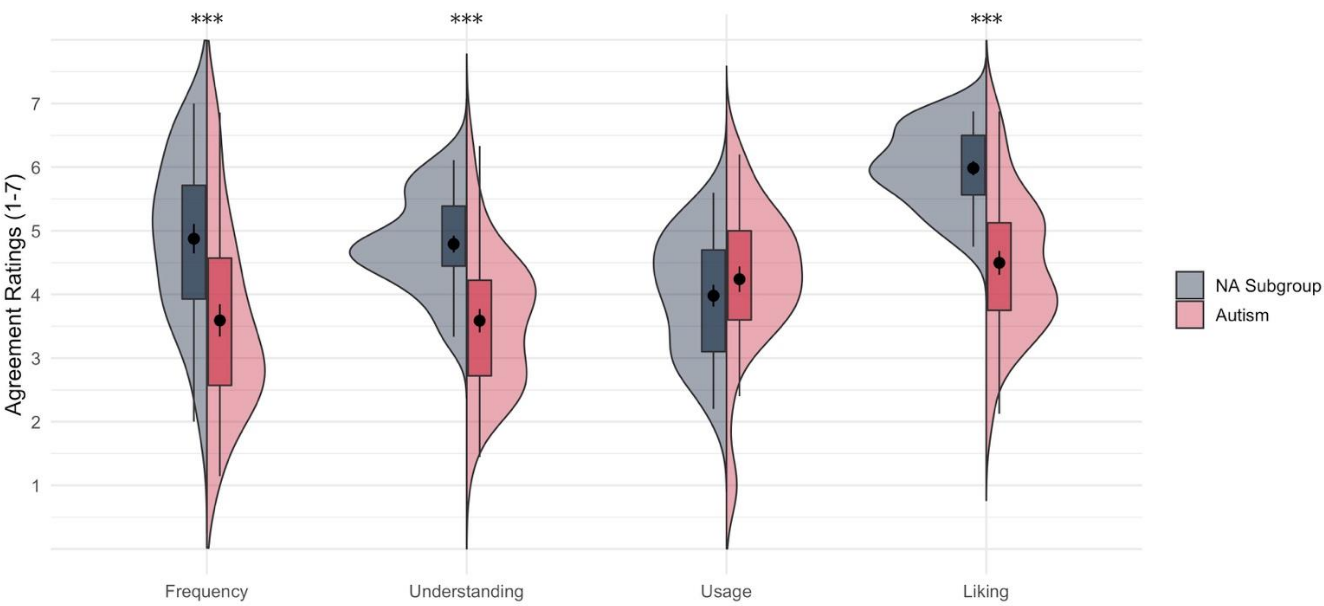


Figure 2.2 Average ratings for agreement on four components between the Non-autistic subgroup and Autistic group from the online dataset

Note. Significance stars are the same for NA vs Autism, and for NA subgroup vs Autism on each component. NA = Non-autistic. Dot with short line = mean ± 1SE. Significance code: $p < .001$ = ***.

2.5 Discussion and Conclusion

The current study aimed to investigate whether self-reported everyday laughter experiences would differ between autistic adults and non-autistic adults via a laughter questionnaire. Overall, the results from the in-lab dataset and supplementary online dataset were consistent. In this exploratory study, we found self-reported laughter behaviour differed between autistic and non-autistic adults; specifically, non-autistic adults reported that they laugh more often (Frequency) and they like laughter more (Liking) than autistic adults did, and are better at understanding other's laughter (Understanding) than autistic adults. However, non-autistic and autistic adults reported that they use laughter for its positive social effects (Usage) to the same degree.

In general, our self-reported data is in line with existing literature, which indicated a different pattern of laughter production and perceptual in autistic people (e.g., (Auburn & Pollock, 2013; Bauminger et al., 2008; Helt & Fein, 2016a; Hudenko et al., 2009; Reddy et al., 2002). At the production level, autistic adults reported a lower frequency of laughing than non-autistic adults in everyday life. This result could be explained by previous observational findings: autistic children rarely laughed in response to social events or used laughter as a social signal in response to or joining other's laughter during social play (Helt & Fein, 2016a; Hudenko et al., 2009; Reddy et al., 2002). Autistic adults likely show a normal amount of production of genuine laughter as autistic children predominantly produce ‘voiced’ laughter to express their genuine and positive emotions (Hudenko et al., 2009; Hudenko & Magenheimer, 2012). However, the abovementioned evidence demonstrated that autistic adults are likely to laugh less in response to social cues or social situations. In our daily interaction, laughter predominantly occurs in conversation acting as a communicative tool, therefore, it is not surprising that autistic adults reported a lower frequency of laughter production as they show less social laughter and use the social meaning of laughter in social communication. At the perception level, autistic adults reported less liking of laughter and less understanding of the social meaning of other’s laughter than non-autistic adults. It could be mainly due to autistic adults having difficulty understanding the mental states of others, therefore, it is also challenging for them to interpret the meaning and intention behind other’s laughter, especially under social ambiguity. As previous studies found that autistic children rated Tom and Jerry cartoons as less enjoyable when a laugh track is superimposed upon the cartoon, and they also laughed less when watching the cartoon with a laughter track than their typical developing peers did (Helt & Fein, 2016). Therefore, autistic adults might easily find other people’s laughter less enjoyable and less contagious because of a poorer interpretation of laughter.

Interestingly, we found no difference in using laughter for its positive social effects between non-autistic and autistic adults. As mentioned above, autistic children display different laughter production and usage patterns relative to their non-autistic peers (Helt & Fein, 2016a; Hudenko et al., 2009; Reddy et al., 2002), therefore, we expected autistic and non-autistic adults would show a difference in the Usage of laughter, in particulate, autistic adults would show a less usage of laughter for its social effects than non-autistic adults. There are several explanations for this result, firstly, our participants were high IQ autistic adults, and they are rather different to the autistic children who were tested in previous studies and therefore are not representing the whole population of autistic people. Secondly, autistic people might also laugh socially as they are adapting and operating themselves in social environments that are mainly shaped by non-autistic people, namely social camouflaging (Cook et al., 2021; Mandy, 2019). Additionally, social camouflaging can have benefits for establishing relationships with non-autistic people (Mandy, 2019). Therefore, autistic people might experience delay and are slow in the development of employing strategies and behaviour to cope with the social norms of laughter behaviour formed by non-autistic people, such as intentionally using laughter or laughing more in daily interaction. Finally, there are limitations of the self-reported measure and hence the result is inadequate to reflect the real situation. It is noteworthy that the quality of the self-reported questionnaire is influenced by individual self-awareness and also somehow affected by reputation management. Especially the items in the Usage component explicitly measure the circumstance in that people laugh on purpose to achieve some kind of social purpose. For instance, “I often laugh deliberately to show that I like someone” and “Sometimes I laugh to stop other people from getting angry with me”. It is possible that autistic adults have a less good insight into their own social communication behaviour, they might think they are generally good at using laughter to cope with these social situations but actually, they may not behave in the same way. For non-autistic adults, they might not aware they laugh intentionally and on purpose in these contexts, in other words, they produce volitional laughter spontaneously in these situations. Therefore, non-autistic adults might feel awkward about these statements of achieving a certain social purpose by laughing intentionally and thus they gave a lower rating on the agreement.

Given that we found a group difference in the baseline mood measure, it is important to consider the potential influence of mood and mental health factors when interpreting results from self-reported questionnaires in autistic individuals. Autistic people are known to have higher rates of co-occurring mental health or psychiatric conditions (Lai et al., 2019), such as anxiety and depression, which may affect their everyday laughter experience. These conditions could potentially impact autistic people's perception and production of their own laughter, as well as their ability to interpret and respond to other's laughter. Therefore, it is important to take into account the potential influence of these factors when studying laughter in autistic people. Unfortunately, we did not collect and control depression and anxiety scores in either the in-lab or online datasets. While the ANCOVA analysis for the online sample controlled for baseline mood score, the results yielded the same findings of a group difference on the Frequency, Understanding and Liking components of the laughter questionnaire as both the in-lab and online samples. However, it is still worth considering mental health factors and controlling for them in future studies to ensure a stronger interpretation of the differences in everyday laughter experience between autistic and non-autistic adults.

In summary, we found differences between autistic and non-autistic adults in the personal experience of laughter behaviour: autistic adults reported that they laugh less, like laughter less in general and they find it more difficult to understand the social meaning of other people's laughter. However, autistic adults reported that they laugh on purpose as often as non-autistic adults, using intentional and deliberate laughter to mediate social contexts. Together, these findings provide valuable evidence of the lived experience of laughter behavioural in autistic adults, especially reflecting their subjective judgments and perceptions of laughter performance in real life (Dang et al., 2020). Based on the evidence from the current first-person experience, we further explore the difference in laughter production and perception between autistic adults and non-autistic adults in lab settings by using well-controlled behavioural and neuroimaging measures in the following chapters to pinpoint the role of laughter as a social communicative tool in human interactions and its underlying neural mechanism.

2.6 Appendix 2A

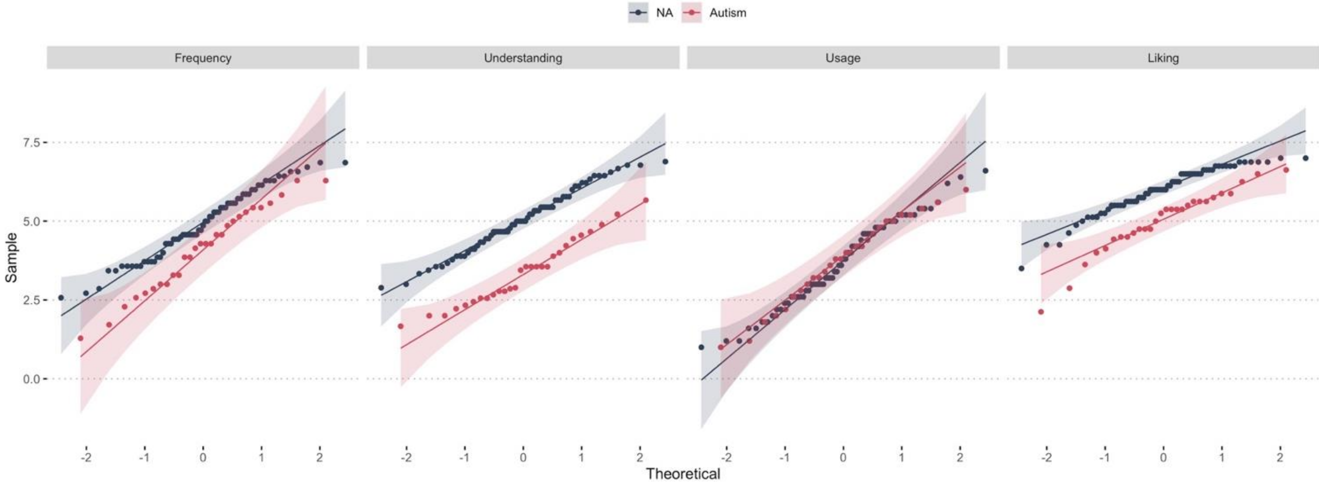


Figure 2.3 Q-Q plots for ratings on four components in the Non-autistic and Autistic groups from the in-lab dataset

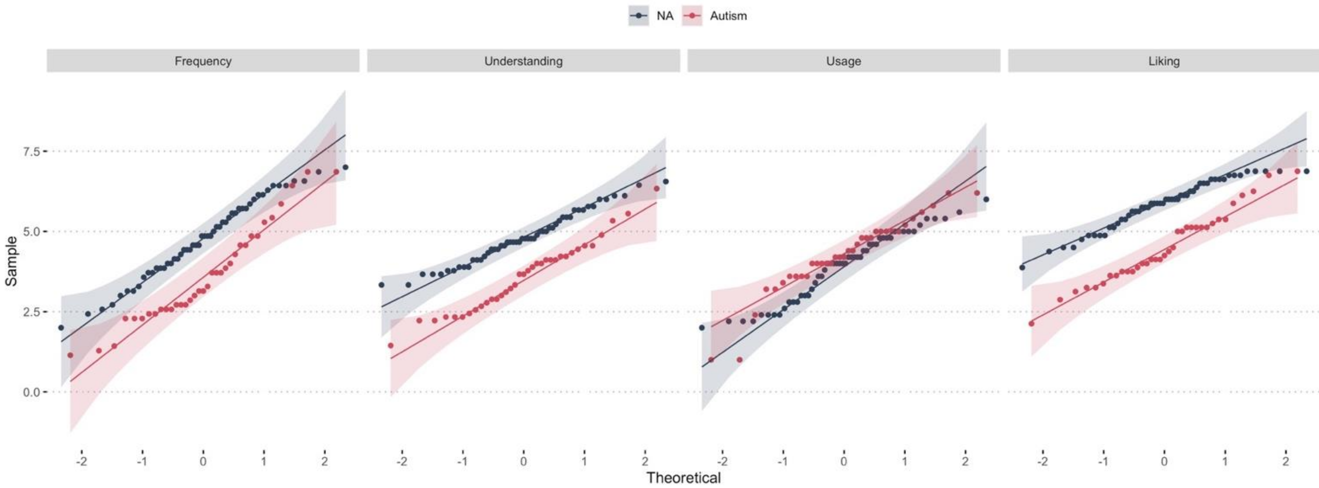


Figure 2.4 Q-Q plots for ratings on four components in the Non-autistic and Autistic groups from online dataset

2.7 Appendix 2B

The information on the psychometric properties of the Laughter Questionnaire is sourced from Muller. M, Cai, C. Q., Lima, C., Scott. S. K., in prep.

Principal components analysis. A principal components analysis was conducted on the responses to the 30 items. The Kaiser-Meyer-Olkin measure verified the sample adequacy for the analysis, KMO = .88. All KMO values for individual items were > .71. Bartlett's test of sphericity indicated that correlations between items were sufficient for PCA, $\chi 2(435) = 8284.97$, $p < .001$. Based on our exploration, we performed a PCA with oblique rotation and defined a number of four components a-priori. The four extracted components had seven, nine, five, and eight loading items with sums of squared loadings of 4.59, 4.50, 2.65, and 4.62, respectively. One item ('Hearing people faking laughter irritates me') did not load on any of the four components and therefore did not contribute to the final solution. Based on the interpretation of the items that clustered on the same components, the four components were labelled Frequency (F), Understanding (UN), Usage (US), and Liking (L). See Table 2B.

Table 2B Four extracted principal components and their loading items, English version (N = 823)

	Loading
Frequency (F)	
I rarely laugh when I am on my own. *	-.58
I have a subdued laugh. *	-.70
I find things funny, but I rarely laugh out loud. *	-.82
I laugh less often than most people I know. *	-.68
I laugh more than most people I know.	.68
I rarely break into uncontrollable laughter. *	-.72
If I find something funny, I often laugh out loud.	.71
Understanding (UN)	
I can tell when people are laughing because they want something from me.	-.63
I can tell when someone is laughing to stop me getting angry at them.	-.63
I can tell when someone is deliberately laughing to pretend that they are amused.	-.76
I can never tell if someone is deliberately laughing to pretend that they are amused. *	.73
I can never tell if someone is laughing because they want something from me. *	.72
I can never tell if someone is laughing to stop me getting angry with them. *	.66

Sometimes I find it difficult to tell when someone is laughing nastily. *	.64
Sometimes I find it difficult to tell when someone is laughing just to be polite. *	.73
I can always tell if someone is laughing at or with me.	-.65
Usage (US)	
I often laugh deliberately to show that I like someone.	.73
I laugh more when I want people to like me.	.67
Sometimes I laugh to stop other people from getting angry with me.	.72
I sometimes laugh to avoid expressing sadness.	.65
I often laugh to avoid expressing frustration.	.60
Liking (L)	
Hearing laughter makes me nervous. *	-.54
I dislike people who laugh a lot. *	-.53
When I am upset, hearing someone laugh makes me feel better.	.64
If I am happy, hearing someone laugh makes me even happier.	.72
I enjoy the sound of people laughing.	.80
A friend's laughter is always good to hear.	.70
Laughter has a positive influence on interactions with people.	.70
I find laughter an important part of intimate relationships.	.50

Note. * The scoring of these items is reversed. The item ‘Hearing people faking laughter irritates me’ did not contribute to either of the four components and is therefore not shown in this table.

Correlations of components. Frequency was positively correlated with Understanding ($r = .15$, $p < .001$), Usage ($r = .11$, $p < .01$), and Liking ($r = .51$, $p < .001$). Further, Understanding was positively correlated with Liking ($r = .23$, $p < .001$). Although the four correlations are significant, they have only small to medium effect sizes according to Cohen’s convention. All other correlations were < .1 and are therefore not reported.

Reliability of components. The internal consistencies of the four components were assessed with the Cronbach’s alpha coefficient and ranged from acceptable to good: Frequency, .84; Understanding, .86; Usage, .73; and Liking, .80. The component Usage had a slightly smaller alpha (‘acceptable’) than the other components, which may result from the small number of five items. Excluding single items from the four scales never increased their internal consistencies, indicating that all items associated with a component share an underlying dimension.

Test-retest reliability. In the original dataset, only a further small group of 35 participants (22 female; mean age = 25.4 ± 5.02 years) contributed to the test-retest reliability analysis. Participants were asked to complete the laughter questionnaire at two time points T1 (testing day) and T2 (two weeks later). Paired-samples t tests indicate that scores on the components frequency, understanding, and usage did not differ significantly between T1 and T2: Frequency, $t(34) = -0.72$, $p = .48$; Understanding, $t(34) = -0.68$, $p = .5$; Usage, $t(34) = -1.49$, $p = .14$. Since the ratings on Liking component was not normal distributed, a related-samples Wilcoxon signed ranks test was conducted and the median liking scores did not differ significantly between T1 and T2, $z = -1.28$, $p = .201$.

Chapter 3. You Make Me Laugh! A Dyadic Study of Friends, Strangers and Neurodiversity

3.1 Abstract

Laughter serves as a communicative tool in daily interaction. Previous research found that autistic children used laughter to express happiness and mirth, but rarely used it for social purposes compared to their non-autistic peers. To date, no research has studied laughter behaviour in autistic adults with high IQs. The current study aims to investigate 1) the difference in laughter behaviour between pairs of one autistic and one non-autistic adult (MIXED dyads) and age-, gender- and IQ-matched pairs of two non-autistic adults (NA dyads); 2) whether the closeness of relationship (Friends/Strangers) would influence laughter production in MIXED and NA dyads. We filmed 30 MIXED and 29 NA Strangers dyads and 7 MIXED and 12 NA Friends dyads engaged in a conversation and a funny video-watching task. Their laughter behaviour was extracted, quantified and annotated. We calculated the duration of Total, Shared and Unshared laughter in each dyad. Regardless of the closeness of the relationship, MIXED dyads produced significantly less laughter than NA dyads in both the conversation and video-watching tasks. Strikingly, NA dyads produced more laughter when interacting with their friend than with a stranger, whilst the amount of laughter in MIXED dyads did not differ when interacting with their friend or a stranger. Autistic and non-autistic adults, when interacting together, generally used laughter less as a communicative signal during social interaction, and the amount of laughter they produced was less influenced by the closeness of the relationship. This may indicate that autistic adults show a different pattern of laughter production relative to non-autistic adults during social communication. However, it is also possible that a mismatch between autistic and non-autistic communication, and specifically in existing

friendships, may have resulted in patterns of laughter production more akin to that seen between strangers.

3.2 Introduction

In chapter 2, we found that autistic adults reported that they laugh less, enjoy laughter less and find it more difficult to understand the social meaning of other people's laughter compared to non-autistic peers. However, autistic adults reported that they laugh on purpose as often as non-autistic adults, using intentional laughter to mediate social contexts. This finding from self-reported experience leaves the open question of whether and how laughter behaviour differs in autistic and non-autistic adults in 'real-world' interactions.

As stated in Chapter 1, laughter is a pervasive nonverbal human behaviour: a combination of stereotypic vocal elements associated with unique facial expressions and rhythmic body movements (Ruch & Ekman, 2001; Sauter et al., 2010). As a ubiquitous vocal signal, laughter plays a critical communicative role in human interaction and therefore is universally recognised across cultures (Sauter et al., 2010; Scott et al., 2014)

Laughter is highly contagious and strongly mediated by social contexts. Researchers found that the amount of laughter positively correlates with a group or audience size and the degree to which the individuals involved have an intimate/familiarity relationship (Bachorowski et al., 2001; Gray et al., 2015; Provine, 1992, 2004; Smoski & Bachorowski, 2003). We laugh more frequently when interacting with others than alone (Provine & Fischer, 1989; Trouvain & Truong, n.d.; Vettin & Todt, 2004), and our laughter can be easily elicited by hearing others' laughter (Provine, 2004). For instance, studies found that participants laughed significantly more when watching funny videos in the presence of a laughing partner (Addyman et al., 2018; Weber & Quiring, 2017). Furthermore, laughter is commonly found in conversation. Most of the conversational laughter produced by individuals is not associated with humour, but most often occurs after their own and their partner's utterances (Provine, 1993; Vettin & Todt, 2004). These functions that laughter conveys in conversation, e.g., showing friendliness, affiliation, agreement to others, and regulating the flow of interaction, indicate that laughter is an intrinsically social behaviour (Alter & Wildgruber, 2018; Scott et al., 2014; Vettin & Todt, 2004). The deep evolutionary root of laughter has led to the proposal that laughter promotes group cohesion and social bonding in human interaction (R. I. M. Dunbar et al., 2012; R. Dunbar & Mehu, 2008).

Laughter not only promotes social bonding and builds rapport, but it also reflects real-life social well-being. The amount of laughter produced during an interaction has been found to be highly correlated with an increased likelihood of self-disclosure, a sign of relationship development that enhanced intimacy (Gray et al., 2015). The researcher also found that a specific type of laughter, shared laughter is a crucial indicator of relationship closeness and intimacy. Sharing laughter (i.e., laughing with another person) is accompanied by greater reports of intimacy, positive emotions and enjoyment in social interactions and pairs who laughed together more frequently reflected a greater interest in pursuing a further relationship (Kashdan et al., 2014a; Treger et al., 2013). Smoski & Bachorowski (2003) found that during gameplay, friend pairs produced more antiphonal laughter (i.e., laughter occurring during or within 1 second of an interactive partner's laughter) than stranger pairs. They proposed that since friends had a shared common pleasurable history of laughing together, listening to a friend's laughter might elicit a "conditioned positive affective response" and prompt the listener to join in the laugh.

Besides acting as a sign of relationship closeness, shared laughter is also an indicator of relationship quality and satisfaction. Kurtz & Algoe (2015) found that romantic couples, who shared more coactive laughter (i.e., overlapping laughter between both partners) when talking about their first encounter, reported that they experience better relationship quality and feel more supported by their partner (KURTZ & ALGOE, 2015). A further study from the same authors investigated how shared laughter promotes relationship satisfaction, affiliation and liking (Kurtz & Algoe, 2017). They asked the couples to recall an interaction, and then the author estimated the amount of shared laughter. Interactive partners who shared more laughter reported experiencing more positive and less negative emotions and perceived themselves as "on the same wavelength". Through the estimation of spontaneously elicited shared laughter from a recalled interaction and experimental manipulation of shared laughter in the lab, the authors further suggested the causal role of shared laughter in promoting the quality of the relationship. In other words, when individuals find the same thing laughable, it infers that the two people evaluate the experience or environment similarly, which in turn signifies that they share similar views, values or knowledge, and the information of them being alike promotes liking, affiliation and the overall relationship satisfaction.

However, while it is intuitive to assume that people with closer relationships laughed together more often, some behavioural studies have suggested otherwise. Devereux & Ginsburg (2001) found that stranger dyads laughed more than friend dyads when watching humorous videos; the authors thus argued that interacting with a stranger required displaying a more "appropriate" communicative response and following more closely to social norms, since laughter is vital for establishing social bonds, especially in the initial encounter (Devereux & Ginsburg, 2001). A similar conclusion was drawn by Vettin & Todt (2004), in which no differences in laughter frequencies were found between friend pairs in the conversation condition and stranger pairs in the experimental condition. From these examples, it can be seen that the occurrence of laughter does not always positively correlate with relationship closeness. However, these studies focused on total laughter within interactions but not shared laughter, and drew conclusions based on different experimental conditions: some filmed dyads in conversation but some recorded dyads watching funny videos.

Researchers also noticed shared laughter carrying rich information on social communicative function in conversation. For instance, Jefferson (1979) suggested an "invitation-acceptance" pattern of shared laughter, where the speaker starts laughing or produces within-speech laughter before completing their utterance as an invitation signal for the audience to join in the laughter (Jefferson, 1979). This laughter-invitation hypothesis was tested by Trouvain & Truong (2013), who examined task-orientated dialogues and found that 42.1% of shared laughter followed the aforementioned invitation-acceptance pattern. Jefferson (1979) also noted that the audience could either accept the speakers' shared laughter or decline the speakers' invitation by actively terminating the laughter and replacing the laughter with speech or silence. Analysis of conversation affirmed that shared laughter is commonly presented before topic termination, whilst solo laughter is usually followed by topic continuation (Bonin et al., 2014; Holt, 2010). Therefore, the presence and usage of shared laughter are critical social cues to regulate conversation flow and serve as a vital sign of social reciprocity.

Given its importance as a crucial signal for social communication, it is worth investigating the production of laughter in autistic individuals during naturalistic social interaction. Studies of laughter behaviour in autism have been primarily focused on children, as highlighted in Chapter 1. In general, qualitative and quantitative differences have been found in the amount of laughter produced by autistic children compared to their peers. Specifically, autistic children joined in others’ laughter less; additionally, they rarely laughed in response to various social events and situations relative to their non-autistic peers (Auburn & Pollock, 2013; Bauminger et al., 2008; Helt & Fein, 2016a; Hudenko et al., 2009; Reddy et al., 2002). Given that autistic symptoms and non-verbal behaviours manifest differently in autistic adults, possibly partially due to intervention and the development of compensatory mechanisms (Livingston et al., 2019; Simonoff et al., 2020) as well as more general cognitive developmental changes, autistic adults may use laughter differently compared to autistic children. Therefore, investigating laughter behaviour in autistic adults during real-world interaction could help us better to understand non-verbal social communication in the wider autistic population.

3.2.1 The present study

In the current study, autistic and non-autistic participants have been paired into the Friends and Strangers dyads. All dyads were recorded engaging in conversation and funny video-watching tasks. Laughter behaviour in video recordings was subsequently quantified, annotated and analysed. Taking together all the evidence as mentioned above, laughter behaviour would be expected to be different between pairs of one autistic and one non-autistic adult (Mixed dyads) and age-, gender- and IQ-matched pairs of two non-autistic adults (NA dyads); we further investigated whether the closeness of relationship (Friends/Strangers) would influence laughter production between Mixed and NA dyads. Given the previous reports of autistic children using laughter mainly as an emotional expression but rarely as a social signal (Helt & Fein, 2016a; Trevisan et al., 2018), we expected NA dyads would produce a greater amount of laughter than Mixed dyads. Additionally, relationship closeness would increase the amount of laughter produced by NA dyads: non-autistic adults would laugh more when interacting with a Friend than a Stranger, as previous studies indicated that people laugh more with a familiar person (Bachorowski & Owren, 2001; Provine, 1992, 2004). However, Mixed dyads would show a different pattern of laughter production under the influence of relationship closeness. Since autistic people are less socially motivated to produce laughter as a social communicative tool to influence or manipulate others (Hudenko & Magenheimer, 2012), Mixed dyads are likely to show a comparable amount of laughter production in both Friend and Stranger conditions.

3.3 Method

3.3.1 Participants

In total, 93 participants including 27 autistic adults and 66 non-autistic adults were recruited via Autism@ICN and UCL SONA subject database. The groups (autism vs non-autistic) were matched for verbal intelligence ($t(91) = 1.485$, $p = .141$) and performance intelligence ($t(91) = 1.255$, $p = .245$), as measured by the Wechsler Abbreviated Scale of Intelligence (WASI-II, Wechsler, 1999) and Wechsler Adult Intelligence Scale (WAIS-III/IV) (Wechsler, 2008). However, the two groups differed significantly in gender ($\chi^2(1) = 8.568$, $p = .003$), and age ($t(91) = 4.216$, $p < .001$), with a higher number of female and younger participants in the non-autistic group. Nevertheless, the mean age of the two groups was within a similar age range (25 - 35 years old) and the SD was relatively small. All participants completed the Autism-Spectrum Quotient (AQ; Baron-Cohen et al., 2001), a 50-item self-assessment questionnaire examining autistic traits: the groups differed on AQ, $t(91) = 9.282$, $p < .001$. Furthermore, autistic and non-autistic participants differed in depressive symptoms as measured by Beck's Depression Inventory ($t(91) = 4.062$, $p < .001$) (BDI, Beck et al., 1961) and alexithymia as measured by the 20-item Toronto Alexithymia Scale (TAS-20; Bagby et al., 1994), ($t(91) = 6.750$, $p < .001$); this was expected as autism is associated with greater risk for depression and alexithymia (Kinnaird et al., 2019) (See Table 3-1).

All participants in the autism group had a diagnosis of autism spectrum disorder (*n* = 12) or Asperger syndrome (*n* = 15) from a qualified clinician. The Autism Diagnostic Observation Schedule (ADOS-2, module 4; Hus & Lord, 2014) was used to verify this diagnosis. Seventeen autistic participants either met the criteria for autism (*n* = 13) or the autism spectrum classification *(n* = 4). The remaining eight participants scored below the threshold, and two did not complete the ADOS, but all were retained within the sample because they reported significant social difficulties in everyday life on the AQ (four had a score above the cut-off considered to indicate clinical levels of autistic traits, and one had a score just one point below this clinical cut-off) and showed symptoms on the ADOS, albeit subthreshold. Furthermore, the ADOS is less sensitive in detecting autism in high-IQ cases (Kamp-Becker et al., 2013).

Table 3-1 Demographics and questionnaires table

	Autism group	**NA group**
N (female)	27 (5)	66 (34)**
Age (years)	33.889 (6.339)	27.606 (6.596) ***
Verbal IQ	114.852 (16.031)	119.940 (14.559)
FSIQ	113.519 (16.787)	117.742 (15.402)
AQ	32.889 (10.020)	14.788 (7.865) ***
ADOS total [a]	9.040 (4.208)	-
- Communication subscale	2.68 (1.749)	-
- Social subscale	6.360 (3.053)	-
BDI	12.778 (7.526)	6.576 (6.315) ***
TAS-20	55.963 (11.005)	40.621 (9.493) ***

Note. Values are given as mean (standard deviation) unless stated otherwise. NA = non-autistic; ADOS = Autism Diagnostic Observation Schedule; AQ = Autism-Spectrum quotient, BDI = Beck's Depression Inventory; TAS-20 = 20-item Toronto

Alexithymia Scale. [a] Two autistic participants did not complete the ADOS. Significance is shown when compared with the Autism group: * = $p < .05$; ** = $p < .01$; *** = $p < .001$.

Participants recruited from the Autism@ICN database were asked to bring a person with whom they had a significant relationship (romantic partner, friend or family member). Within the autistic group, two of them brought their autistic friends, six of them brought their NA friends/romantic partners, and one of them brought his NA sibling; within the NA group, 12 of them brought their NA friends. The rest of the participants were paired with a stranger, and thus contributed to a total of 84 dyads with three types of pairs: 30 Mixed dyads (autistic paired with non-autistic), 29 NA dyads (non-autistic paired with non-autistic) and 4 AA dyads (autistic paired with autistic) in Stranger conditions, while in the Friend condition, there were 7 Mixed dyads, 12 NA dyads and 2 AA dyads. Notably, to increase the number of dyads, each participant took part in two dyads, either one Friend dyad and one Stranger dyad or two Stranger dyads. (see Figure 3.1). Owing to the small number of AA dyads, we only further analysed the performances of Mixed and NA dyads. Descriptive information on dyad comparison is shown in Table 3-2.

Table 3-2 Dyad Comparison

	AA (N = 6)	NA (N = 41)	MIXED (N = 37)	Dyad Comparison NA vs MIXED (p-value)
Gender (Same: Different)	4:2	32:9	26:11	.432
Age avg	33.000 (4.037)	28.256 (4.908)	30.432 (4.612)	.048
Age diff	5.667 (4.412)	7.585 (6.637)	7.946 (6.485)	.809
VIQ avg	113.750 (10.501)	120.500 (10.3346)	117.068 (12.213)	.183
VIQ diff	24.167 (13.348)	17.439 (11.698)	14.460 (11.192)	.255
FSIQ avg	115.333 (14.130)	118.512 (10.570)	114.838 (12.097)	.156
FSIQ diff	25.667 (10.309)	17.220 (10.905)	15.946 (9.507)	.586
AQ avg	33.250 (3.883)	15.366 (5.412)	23.581 (7.612)	.000
AQ diff	8.167 (5.636)	9.415 (6.874)	19.054 (11.609)	.000
BDI avg	10.667 (4.401)	6.768 (4.221)	10.122 (5.201)	.002
BDI diff	8.333 (7.916)	7.683 (6.170)	10.189 (5.999)	.073
TAS20 avg	55.667 (3.601)	41.988 (6.151)	46.635 (8.129)	.005
TAS20 diff	11.667 (10.708)	12.415 (7.801)	19.216 (13.195)	.008

Note. Values are given as mean (standard deviation) unless stated otherwise. In the gender description, 'Same' refers to both participants in a dyad who were of the same gender. In contrast, 'Different' refers to participants in a dyad of different gender. N = number of dyads, avg = average value calculated from both participants in a dyad, diff = difference between participants in a dyad; VIQ = Verbal IQ, FSIQ = Full-Scale IQ, AQ = Autism-Spectrum quotient, BDI = Beck's Depression Inventory; TAS-20 = 20-item Toronto Alexithymia Scale.

3.3.2 Equipment and materials

In the present study, we performed multimodal recordings from 84 dyads. Participants within a dyad were assigned to be either the 'Blue' or the 'Yellow' participant for clear distinction of recording files. Two LED light sources were stationed next to the participants to illuminate facial features. During the experiment, the experimenters remained in the room, and were separated from the participants by a curtain, and they did not interfere with the interaction.

3.3.2.1 Audio and video recording

Alongside the non-verbal elements, wearable microphones connected to an audio mixer were attached to each participant's chest and used to collect the verbal component of the interaction. Each participant's voice was recorded on two separate channels of a single audio file using the Audacity software. A Canon camera and a Logitech webcam were also used to record the whole session.

3.3.2.2 Video stimuli

Two sets of humorous video stimuli with a length of 5min 50s of each set were used in the video-watching task. Both sets were composed of three clips of TV hosts bursting into uncontrollable laughter and two clips of Tom and Jerry cartoons (2min 26s in Set 1; 2min 27s in Set 2). The former content aimed to elicit participants' laughter by contagion, and the latter was used as a slapstick cartoon. Since slapstick cartoons are devoid of social communication, understanding and appreciating such humour content does not require mentalizing ability; previous research has indicated that autistic people enjoy the humour of slapstick videos (Silva et al., 2017), and no differences were found in humour ratings between autistic and NA participants when slapstick videos were used as stimuli (Samson & Hegenloh, 2010). Tom & Jerry cartoons have also been used in a previous experiment investigating the effect of background laughter on media enjoyment in autistic people (Helt & Fein, 2016a). All the videos were downloaded from YouTube, and sets were trimmed and edited with Adobe Premiere Pro CC 2018 (Version 13.0; Adobe, 2018). The order of the sets was counterbalanced between dyads (i.e., friends or strangers). This way, each participant saw both sets of videos as each person participated in two dyads.

3.3.2.3 Questionnaires measures

In addition to the multimodal testing, we also assessed dyad and group differences in alexithymia with the 20-item Toronto Alexithymia Scale (TAS-20; Bagby, Parker, & Taylor, 1994) and depression with the Beck Depression Inventory (BDI; Beck, Ward, Mendelson, Mock, & Erbaugh, 1961). The Relationship Closeness Inventory (RCI; Berscheid et al., 1989) was used to assess the quality and duration of the relationship between the participants and their partners as a baseline measure between friends' dyads.

3.3.2.4 Experimental procedures

The study consisted of three dyadic interactive tasks: an ice-breaker task, a conversation task and a video-watching task. When participants arrived at the testing room, they received a brief outline of the upcoming tasks (See Figure 3.1), which would last approximately 30 minutes. The specific instructions for each task were explained before the start of each task.

To create a comfortable social situation and increase the likelihood of participants producing laughter during the testing, participants were not told that the experiment was about laughter expression; they were informed that the experiment aimed to study motion synchronization in different social situations. Therefore, participants were also aware that the sessions would be audio- and video-recorded. Importantly, all the participants were not told they might be paired with an autistic person except the Friend dyads. Although there were a few non-autistic participants aware that their partner might be autistic, however, they were only told and confirmed about this after the testing.

For the ice-breaker and conversation task, participants were instructed to sit face-to-face on small stools positioned one metre apart. For these two tasks, an audio cue (beep sound) was played via the speaker to mark the start, and the end of the task and the participants were asked to clap hands with each other three times as a synchronization action for later video processing.

After two experimenters set up and tested the speakers and camera, participants were informed that the experiment would begin with a four-minute ice-breaker task as a warm-up conversation. Friend dyads were asked to discuss ‘how you have met and what you thought about each other’, while stranger dyads were asked to play the “Two Truths and A Lie” game, taking turns to share three statements about themselves and discussing their guesses about each other’s lies. Participants were asked to come up with three new statements each time.

Next came the six-minute conversation task. Two slightly different conversation topics were available for participants assigned to more than a dyad. The topic instructions were given as follows: “please describe the food (/vegetables) you dislike and discuss how to make a (vegetarian) meal together only using food you both dislike”. These topics were adapted from (Chovil, 1991), who designed the task for studying facial expression, and similar topics have been used in a study which investigated social interaction between autistic and NA participants (Georgescu et al., 2020). These two topics were counterbalanced between dyad types (i.e., friends or strangers). The blue participant in the dyad was asked to start the session.

Participants received a short break before the video-watching task, which allowed the experimenter to reset the testing equipment, such as table, laptop and earphones. Participants were also instructed to sit side by side and wear only one earphone which allowed them to hear each other’s conversation and laughter. The video stimuli were presented on a laptop (Apple MacBook Pro, 15-inch). Participants were asked to count to three simultaneously as a synchronization action before and after the video was played. This video-watching task lasted for about six minutes.

In the final part of the experiment, participants filled in pen-and-paper questionnaires: TAS-20, BDI, and participants in the friend dyads also completed the RCI. Lastly, participants were debriefed and paid. Informed written consent was obtained prior to testing, and the project received approval from the UCL research ethics committee.

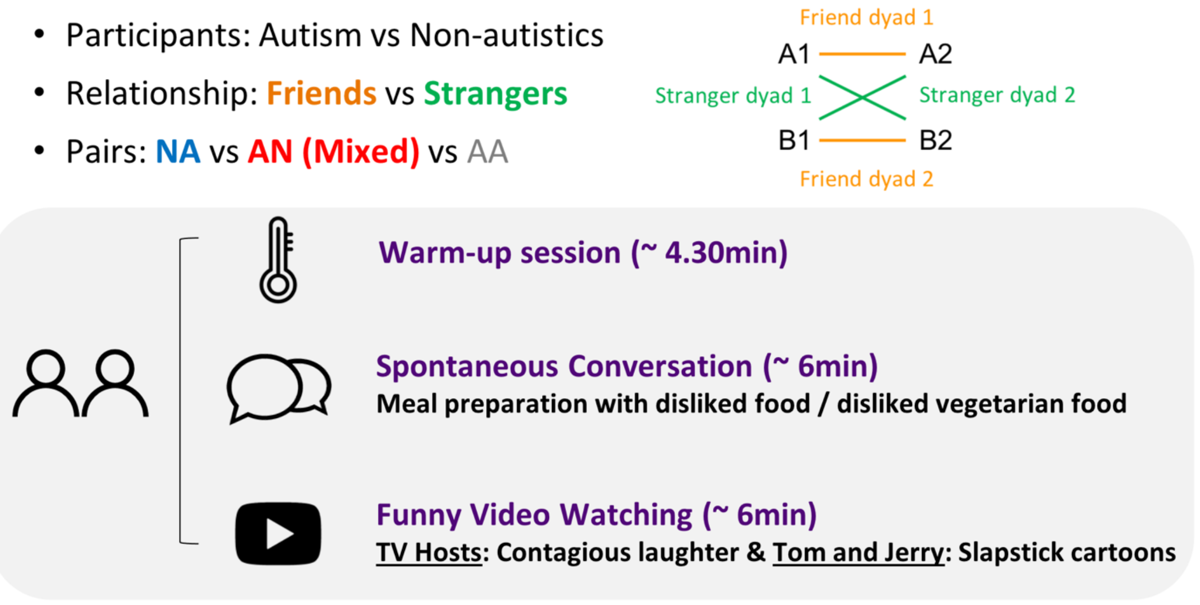


Figure 3.1 Experiment design and procedure

3.3.3 Laughter annotation

3.3.3.1 Laughter extraction

The video recordings of each participant in a dyad during the conversation were synchronised by audio using Adobe Premiere Pro CC 2020 (Version 14.3.1; Adobe, 2020), resulting in composite videos showing two participants side by side simultaneously. These videos were exported in H.264 video format and were then imported into ELAN (Version 5.2-beta; Sloetjes & Wittenburg, 2008) for laughter annotation and extraction. The same synchronisation procedure was applied for the recordings of the video-watching task only when the first camera could not capture both participants. The conversation and video-watching recordings from each participant were screened for laughter, and the rate of the recordings was slowed down by 50% to annotate the onset and offset time more precisely. The onset times, offset times and durations (in milliseconds) of laughter were exported to spreadsheets for further processing and analysis.

3.3.3.2 Laughter definition

We adopted the definition of laughter onsets and offsets from previous studies (Helt & Fein, 2016a; KURTZ & ALGOE, 2015; Vettin & Todt, 2004), in which not only vocalisation but also body movement and facial expressions were taken into consideration for the annotation of laughter. The use of both auditory and visual cues to identify laughter also improved recognition accuracy (D'Mello et al., 2018). Laughter onset was defined as the start of an audible exhalation — both voiced (typical laughter with song-like quality and often presented with vowel-like sounds, e.g. /ha/ or /hi/) and unvoiced (more nasal-sounding laughter associated with a grunt or snort and often presented with fricatives, e.g. /fff/; (Alter & Wildgruber, 2018) or the start of laughter-related movements, for instance, visible shaking or vibration of the throat, shoulders or chest and swift amplification of positive facial expression. Therefore, closed-mouthed or covered-up laughter was also accounted for. During the conversation session, we noticed participants sometimes spoke with a higher pitch and had a laughing tone in their speech; such speech-laughs were accompanied by characteristic breathing and prosodic pattern of laughter (Nwokah et al., 1999), and hence also considered as laughter. The offset of laughter was defined as the beginning of the deep inhalation that was posited at the end of a laughing episode. When such inhalation was absent, we considered the offset as the last moment of the audible laugh or observable laughter-related behaviour.

3.3.3.3 Laughter coding scheme

Based on the above definition of onsets and offsets, laughter episodes were annotated whether the laughter was proceeded by an utterance made by the person laughing (own utterance) or by an utterance produced by their partner (other utterance) in the conversation task. As participants were allowed to interact with each other during the video watching, an additional annotation, 'laughter elicited by video' (video), was added to distinguish laughter without any preceding utterance in this specific task.

In both conversation and video-watching tasks, we further categorized laughter episodes into 'Shared laughter' or 'Unshared laughter' episodes (See Figure 3.2):

- Shared laughter episode: both participants laughed together or in close succession (laughter produced during or within 1 second of the partner's laughter offset)
- Unshared laughter episode: One participant started laughing, but their partner did not laugh within 1 second of the offset of the first participant's laughter

Within the Shared laughter episodes, two speakers' laughter sometimes overlapped with each other; therefore, we further categorized each episode into 'Shared-Overlap laughter' and 'Shared-Nonoverlap laughter' episodes. Also, we annotated the 'Coactive laughter' and 'Hanging laughter' specifically in the Shared-Overlap laughter episodes since a previous study had demonstrated a correlational relationship between relationship quality and coactive laughter produced simultaneously.

- Coactive laughter: Overlapping laughter produced by both participants.
- Hanging laughter: Residual laughter after coactive laughter within a shared episode

Based on the above definition and coding scheme, all recordings were annotated and coded by one researcher (M.Y. Tsai) to reach the best consistency across dyads; a second researcher (Q. Cai) only stepped in when the first researcher found the recording's quality to be ambiguous to define the precise onset and offset of laughter episodes.

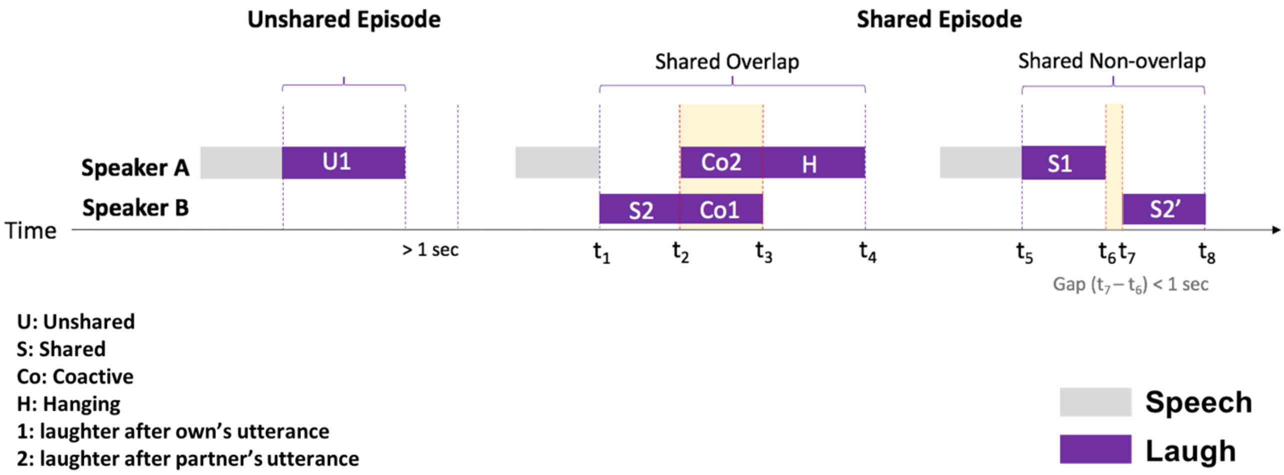


Figure 3.2 Laughter annotation scheme diagram

Note. Figure 3.2 shows three laughter episodes: the first laughter episode (leftmost) was annotated as unshared as speaker B did not join in laughing within 1 second after speaker A stopped laughing. The following laughter episodes demonstrated a common shared laughter pattern. Noteworthy is the extraction of shared laughter duration; the total duration for the first shared laughter episode (Shared-Overlap) is t_4-t_1, while that of the second shared laughter episode (Shared-Nonoverlap) is t_8-t_5 as we treated each onset and offset of laughter as an episode.

3.4 Results

In the scope of this PhD thesis, I focus on the results of laughter annotation at a dyadic level. Upon reviewing the data, laughter frequency did not reflect the actual amount of laughter produced, especially in the video-watching task, where dyads tended to produce lengthy laughter without pauses, resulting in long laughter duration but low laughter frequency. Additionally, the Conversation and Video-watching tasks were designed to be the same length, around 6 minutes, and a paired samples t-test indicated that the length of recordings was comparable between the two tasks, $t(77) = 1.510$, $p = .135$ two-tailed; therefore, our analysis assessed the difference in total laughter duration rather than frequency.

All data were analysed with IBM SPSS statistics software (Version 2) and RStudio Team (2020). Normality was first assessed through Shapiro-Wilk Tests. Although Shapiro-Wilk statistics were significant in many distributions ($p < .05$), a recent study demonstrated that F-tests are relatively robust even for data with a severe violation of normality, i.e. with skewness of 2 and a kurtosis value of 6, and unbalanced groups (Blanca et al., 2017). Therefore, in order to retain as much information as possible from the continuous data (laughter duration), I chose to perform parametric tests in the following analysis.

3.4.1 Pre-analysis

3.4.1.1 Assessment of dependence

I investigated whether assigning participants to a "Blue" or "Yellow" microphone would affect the amount of laughter produced; this analysis was done to ensure the sitting position and who was the conversation starter would not affect laughter behaviour. Paired-sample t-tests showed no significant differences in total laughter duration between participants with Blue or Yellow microphones in the conversation task, $t(77)=.137$, $p = .891$ or in the video-watching task, $t(77) = .176$, $p = .861$, affirming the above assumption.

Intraclass correlation coefficients (ICC) were calculated to estimate the degree of dyadic dependence in laughter production (Kashy & Kenny, 2000). A moderate to good degree of $ICC = .604$ was found, $F(77,78) = 4.052$, $p <. 001$. Because the ICC for the duration of total laughter is computed by dividing the between-dyad variance by the total variance, it can also be interpreted as the proportion of variance due to dyads. Therefore, 60% of the variance in our study variables was due to dyads.

3.4.1.2 The difference in Conversation topics and Video sets

Since we used two conversation Topics and two video stimuli Sets to counterbalance between dyads, we first performed a 2 x 2 ANOVA with Topics (Food vs Vegetarian food) and Pairs (NA vs MIXED) as between-subject variables to check whether the different conversation topics would affect laughter production in conversation. No significant main effect was found on Topics, $F(1,74) = .715$, $p = .401$, indicating that the laughter produced was comparable when dyads were given either topic 1 (disliked food) or topic 2 (disliked vegetarian food). Also, no significant interaction was found in Topics x Pairs, $F(1,74) = 3.411$, $p = .069$, suggesting that the two topics elicited a similar amount of laughter in each type of dyad. Secondly, a 2 x 2 ANOVA with Video Sets (TV Hosts vs Tom & Jerry) and Pairs (NA vs MIXED) as between-subject variables to check whether the different video stimuli sets would affect laughter production in video watching. No significant main effect was found on Sets, $F(1,74) = 2.964$, $p = .089$, indicating that the laughter produced was comparable when dyads watched either Set 1 or Set 2 video stimuli. Also, no significant interaction was found in Sets x Pairs, $F(1,74) = .229$, $p = .634$, suggesting that watching either video set elicited a similar amount of laughter in each type of dyad.

3.4.1.3 Relationship Closeness in Friends dyads

The Relationship Closeness Inventory (RCI; Berscheid et al., 1989) was administered to assess the duration and quality of the relationship closeness between Mixed Friends and NA Friends dyads. RCI revealed no significant differences in terms of duration, $t(10.26) = 1.722$, $p = .101$, and strength $t(19) = .316$, $p = .759$ of friendship, indicating that the relationship closeness was comparable between Mixed Friends dyads and NA Friends dyads.

3.4.2 Laughter production in conversation vs video-watching

3.4.2.1 Total laughter duration

We first investigated whether the dyads differed in total laughter duration among the two tasks; importantly, the total laughter duration is the sum of the duration of unshared and shared laughter episodes on the dyadic level. A 2 x 2 x 2 mixed model ANOVA with Task types (conversation vs video-watching) as a within-subject variable, Pairs (MIXED vs NA) and Relationships (Friends vs Strangers) as between-subject variables was conducted. There was a significant main effect of Task types, $F(1,74)$ = 6.354, p = .014, η_p^2 = .079, indicating that participants produced more laughter in the video-watching task (M = 30.711sec, SEM = 4.201sec) than in conversation task (M = 20.779sec, SEM = 2.081sec). Also, there was a significant main effect of Pairs, $F(1,74)$ = 7.093, p = .009, η_p^2 = .097, indicating that NA dyads (M = 32.845sec, SEM = 3.375sec) produced more laughter than Mixed dyads (M = 18.645sec, SEM = 4.127sec) in general. However, there was no significant main effect of Relationship, $F(1,74)$ = 2.377, p = .127, η_p^2 = .031, indicating that the amount of laughter produced by Friends dyads (M = 29.856sec, SEM = 4.676ses) and Strangers dyads (M = 21.635sec, SEM = 2.561ses) was comparable. There was a significant interaction between Task types x Pairs x Relationship, $F(1,74)$ = 4.877, p = .030, η_p^2 = .062, however, no significant effects were found on two way interactions between Task types x Pairs, $F(1,74)$ = 3.113, p = .082, η_p^2 = .040, Task types x Relationship, $F(1,74)$ = .171, p = .681, η_p^2 = .002, or Pairs x Relationship, $F(1,74)$ = 3.315, p = .073, η_p^2 = .043. Since I found a significant three-way interaction, following a 2 x 2 mixed model ANOVA with Task types (conversation vs video-watching) as within-subject variables and Relationship (Friends vs Strangers) as between-subject variables was conducted by splitting data into Pairs (MIXED vs NA). Within NA dyads, a significant interaction between Task types and Relationship was found, $F(1,39) = 5.530$, $p = .024$, $\eta_p^2 = .124$, and a significant main effect of Task types, $F(1,39) = 14.700$, $p < .001$, $\eta_p^2 = .274$, and a significant main effect of Relationship, $F(1,39) = 5.905$, $p = .020$, $\eta_p^2 = .132$. Within Mixed dyads, there was no significant interaction between Task types and Relationship, $F(1,35) = 1.079$, $p = .306$, $\eta_p^2 = .030$, no significant main effect of Task types, $F(1,35) = .191$, $p = .664$, $\eta_p^2 = .005$, and no significant main effect of Relationship, $F(1,35) = .041$, $p = .840$, $\eta_p^2 = .001$. These results suggest that the interaction between Task types and Relationships was different between Pairs.

Post Hoc analysis indicated that NA Friends (M = 55.416sec, SD = 30.927ses) produced significantly more laughter than NA Strangers (M = 27.158sec, SD = 31.050ses) during video watching, $t(39) = 2.654$, $p = .011$. However, NA Friends (M = 28.203sec, SD = 18.815ses) produced a comparable amount of laughter as NA Strangers (M = 20.604sec, SD = 16.326ses), $t(39) = 1.297$, $p = .202$ in Conversation. The significance level was adjusted using Bonferroni correction for 2 comparisons (p = .025). These findings suggest that relationship closeness has an impact on the amount of laughter produced in NA dyads during video watching but not during the conversation: NA participants produced a greater amount of laughter when they watched funny videos with Friends than with a Stranger. However, there was no difference in the amount of laughter they produced during conversation no matter with a Friend or with a Stranger. In general, no such effect of relationship closeness was found on Mixed dyads in both Conversation and Video watching.

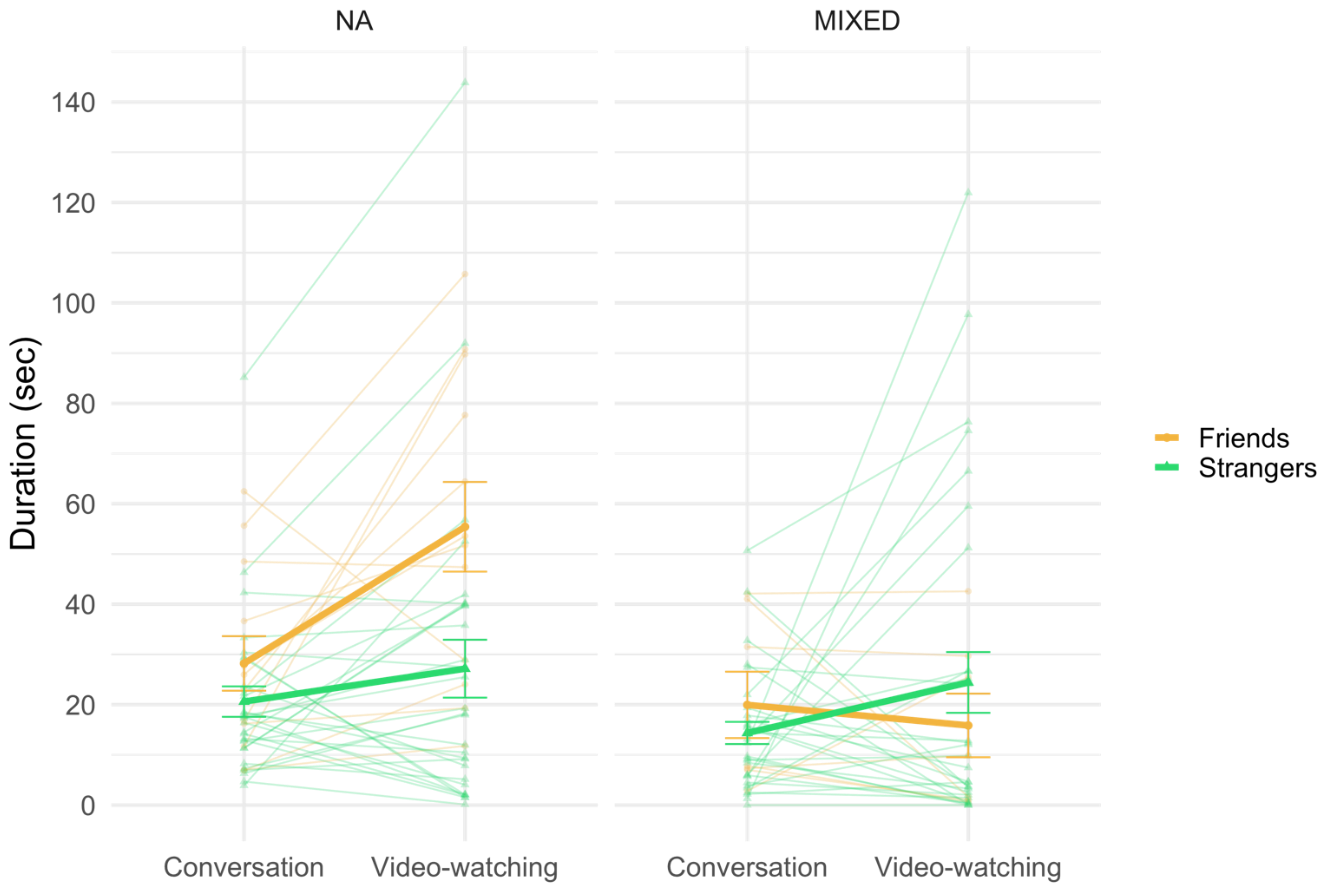


Figure 3.3 The duration of total laughter production

Note. Each light colour line represents the duration of one dyad's laughter production in Conversation and Video-watching tasks. Each dark colour line represents the average duration of laughter production across dyads in Conversation and Video-watching tasks. Error bars: ± 1 SE.

3.4.1.2 Shared laughter duration

We then investigated whether the dyads differed in shared laughter duration among the two tasks. Importantly, here we analysed the sum of the duration of shared laughter episodes on the dyadic level. A 2 x 2 x 2 mixed model ANOVA with Task types (conversation vs video-watching) as a within-subject variable, Pairs (MIXED vs NA) and Relationships (Friends vs Strangers) as between-subject variables was conducted. There was a significant main effect of Task types, $F(1,74) = 11.927$, $p < .001$, $\eta_p^2 = .139$, indicating that participants produced more shared laughter in the video-watching task (M = 20.416sec, SEM = 3.570sec) than in the conversation task (M = 9.900sec, SEM = 1.521ses). Also, there was a significant main effect of Pairs, $F(1,74) = 5.516$, $p = .022$, $\eta_p^2 = .069$, indicating that NA dyads (M = 20.519sec, SEM = 2.890ses) produced more shared laughter than Mixed dyads (M = 9.797sec, SEM = 3.534ses) in general. However, there was no significant main effect of Relationship, $F(1,74) = 2.768$, $p = .100$, $\eta_p^2 = .036$, indicating that the amount of shared laughter produced by Friends dyads (M = 18.956sec, SEM = 4.004ses) and Strangers dyads (M = 11.360sec, SEM = 2.192ses) was comparable.

There was a borderline significant interaction between Task types x Pairs x Relationship, $F(1,74) = 3.743$, $p = .057$, $\eta_p^2 = .048$, and a significant interaction between Task types x Pairs, $F(1,74) = 4.643$, $p = .034$, $\eta_p^2 = .059$, but no significant interaction between Task types x Relationship, $F(1,74) = .004$, $p = .952$, $\eta_p^2 = .000$, or Pairs x Relationship, $F(1,74) = 1.760$, $p = .189$, $\eta_p^2 = .023$. Since we found significant two-way interaction between Task types and Pairs, and a borderline significant three-way interaction, a 2 x 2 mixed model ANOVA with Task types (conversation vs video-watching) as within-subject variables and Relationship (Friends vs Strangers) as between-subject variables was conducted with each of the Pairs types (MIXED vs NA). Within NA dyads, there was a significant main effect of Task types, $F(1,39) = 19.186$, $p < .001$, $\eta_p^2 = .330$, indicating that NA dyads produced more shared laughter in the video-watching task (M = 29.057sec, SEM = 5.025sec) than in conversation task (M =11.980sec, SEM = 2.222ses). And a significant main effect of Relationship, $F(1,39) = 4.125$, $p = .049$, $\eta_p^2 = .096$, indicating that NA Friends (M = 27.345sec, SEM = 5.652sec) produced more shared laughter than NA Strangers (M =13.693sec, SEM = 3.636ses). However, there was no significant interaction between Task types and

Relationship, $F(1,39) = 2.427$, $p = .127$, $\eta_p^2 = .05$, indicating the relationship effect on shared laughter production was not influenced by the type of task. Within Mixed dyads, there was no significant main effect of Task types, $F(1,35) = .722$, $p = .401$, $\eta_p^2 = .020$, and no significant main effect of Relationship, $F(1,35) = .078$, $p = .782$, $\eta_p^2 = .002$, and no significant interaction between Task types and Relationship, $F(1,35) = 1.504$, $p = .228$, $\eta_p^2 = .041$. These findings suggested that relationship closeness had an impact on the amount of shared laughter produced in NA dyads but not in Mixed dyads: NA participants laughed together more often when interacting with a Friend than with a Stranger in both tasks. However, there was no such effect of relationship closeness on Mixed dyads, whether in Conversation or Video watching.

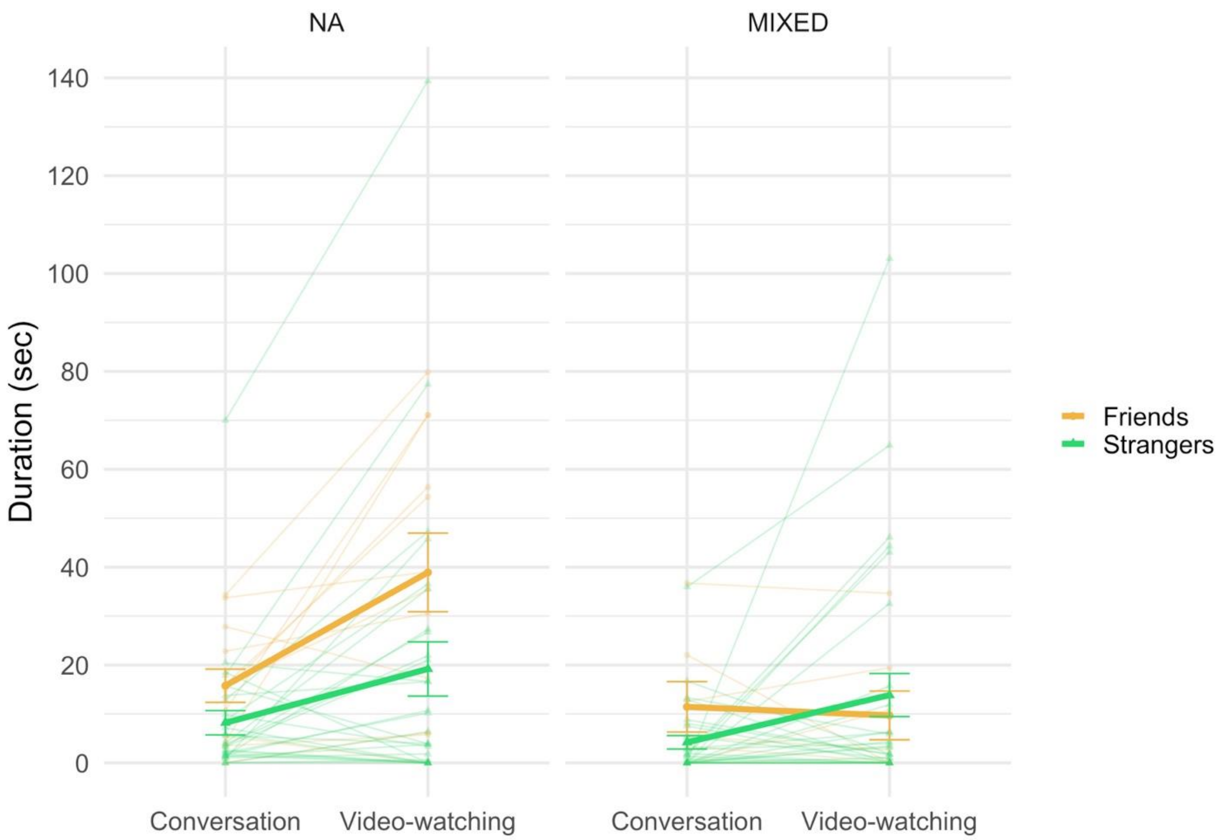


Figure 3.4 The duration of shared laughter production

Note. Each light colour line represents the duration of one dyad's shared laughter production in Conversation and Video-watching tasks. Each dark colour line represents the average duration of shared laughter production across dyads in Conversation and Video-watching tasks. Error bars: ± 1 SE.

3.4.1.3 Unshared laughter duration

Finally, I investigated whether the dyads differed in unshared laughter duration between the two tasks; the duration of unshared laughter episodes on the dyadic level was defined as the sum of the duration of unshared laughter episodes on each participant in each dyad. A 2 x 2 x 2 mixed model ANOVA with Task types (conversation vs video-watching) as a within-subject variable, and Pairs (MIXED vs NA) and Relationships (Friends vs Strangers) as between-subject variables was conducted. There was a significant main effect of Pairs, $F(1,74) = 6.054$, $p = .016$, $\eta_p^2 = .076$, indicating NA dyads (M = 12.918sec, SEM = 1.053ses) produced more shared laughter than Mixed dyads (M = 8.825sec, SEM = 1.288ses) in general. However, there was no significant main effect of Task types, $F(1,74) = .023$, $p = .879$, $\eta_p^2 = .000$, indicating that participants produced a similar amount of unshared laughter in the video-watching task (M = 10.737sec, SEM = 1.406sec) as in the conversation task (M = 11.007sec, SEM = 0.989ses). And there was no significant main effect of Relationship, $F(1,74) = 1.342$, $p = .250$, $\eta_p^2 = .018$, indicating that the amount of unshared laughter produced by Friends dyads (M = 11.835sec, SEM = 1.459ses) and Strangers dyads (M = 9.908sec, SEM = 0.799ses) was comparable.

There was a significant interaction between Relationship x Pairs, $F(1,74) = 7.299$, $p = .008$, $\eta_p^2 = .091$; however, no significant effects were found on the interaction between Task types x Pairs x Relationship, $F(1,74) = .974$, $p = .327$, $\eta_p^2 = .013$, between Task types x Relationship, $F(1,74) = 1.085$, $p = .301$, $\eta_p^2 = .014$, or between Task types x Pairs, $F(1,74) = .005$, $p = .943$, $\eta_p^2 = .000$.

Since we found a significant two-way interaction between Relationship and Pairs, the following Post Hoc analysis indicated that NA Friends produced significantly more unshared laughter than NA Strangers, $t(80) = 3.886$, $p < 0.001$, and NA Friends produced more unshared laughter than Mixed Friends in regardless of Task type, $t(36) = 3.534$, $p < 0.001$. However, no difference in the amount of unshared laughter produced between Mixed Friends and Mixed Strangers, $t(72) = -.807$, $p = .422$ and between NA Strangers and Mixed Strangers, $t(93.112) = -.251$, $p = .803$. The significance level was adjusted using Bonferroni correction for 4 comparisons ($p = .0125$). These findings suggested that relationship closeness has an impact on the amount of unshared laughter produced in NA dyads but not in Mixed dyads: NA participants produced a greater amount of unshared laughter when they interacted with a Friend than with a Stranger. However, there was no difference in the amount of unshared laughter Mixed dyads produced regardless of whether they were paired with a Friend or with a Stranger. Additionally, NA Friends produced more unshared laughter than Mixed Friends in general. In contrast, Strangers dyads produced the same amount of unshared laughter between NA and Mixed dyads.

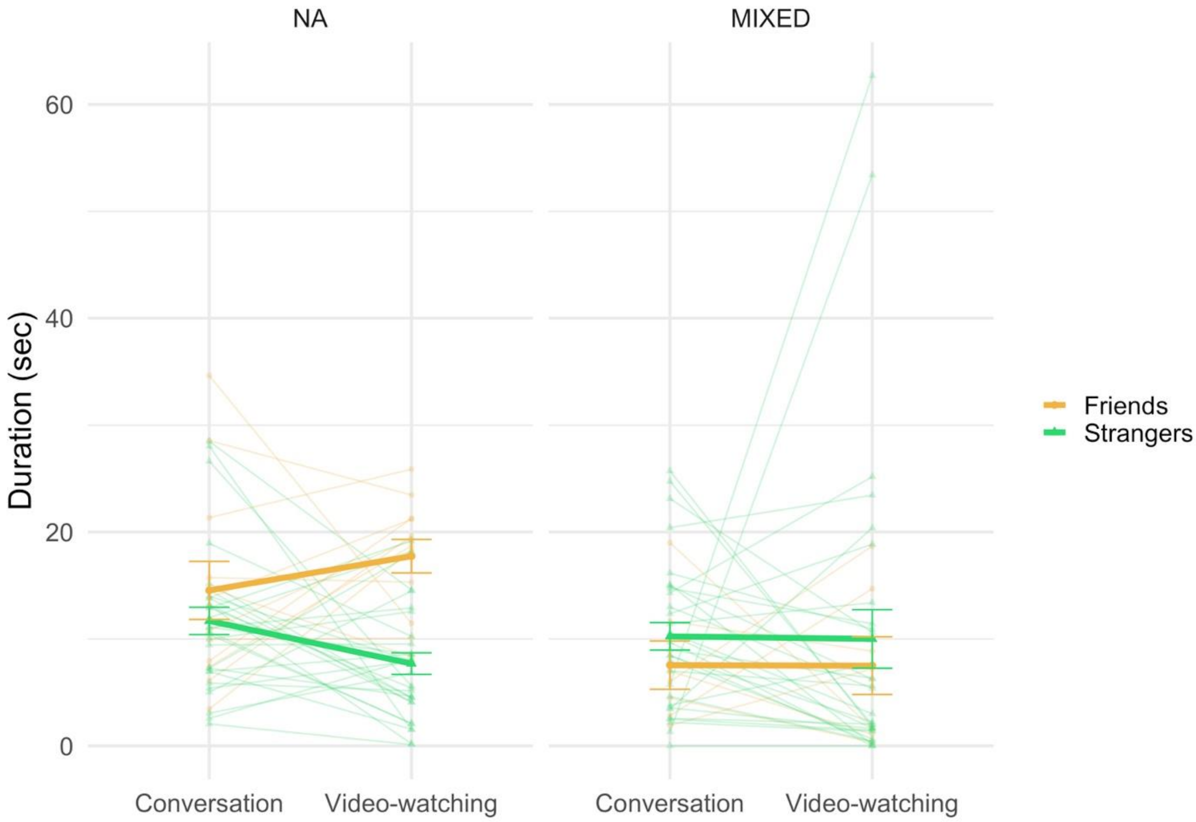


Figure 3.5 The duration of unshared laughter production

Note. Each light colour line represents the duration of one dyad's unshared laughter production in Conversation and Video-watching tasks. Each dark colour line represents the average duration of unshared laughter production across dyads in Conversation and Video-watching tasks. Error bars: ± 1 SE.

3.4.3 Laughter production in video-watching: TV Hosts vs Tom & Jerry

As the video-watching task seemed to drive most of the interactions between Pairs and Relationships, and because the content and length of the TV Hosts and Tom & Jerry videos were not matched in the study design, two separate 2 x 2 mixed model ANOVAs with Pairs (MIXED vs NA) and Relationship (Friends vs Strangers) as between-subject variables were conducted on TV Hosts and Tom & Jerry data with regard to the duration of laughter production.

3.4.2.1 TV Hosts

The duration of total laughter production in watching TV Hosts' videos was analysed. There was no significant main effect of Pairs, $F(1,74) = 3.474$, $p = .066$, $\eta_p^2 = .045$, indicating NA dyads (M = 26.697sec, SEM = 4.522ses) produced a similar amount of laughter as Mixed dyads (M = 13.383sec, SEM = 5.530ses) when watching TV Hosts videos; and no significant main effect of Relationship, $F(1,74) = .250$, $p = .619$, $\eta_p^2 = .003$, indicating that participants in both groups produced a similar amount of laughter when watching TV Hosts regardless of whether they were with a Friend (M = 18.254sec, SEM = 6.266sec) or a Stranger (M = 21.826sec, SEM = 3.431ses). Additionally, there was no significant interaction between Pairs x Relationship, $F(1,74) = 1.863$, $p = .176$, $\eta_p^2 = .025$, indicating that the amount of laughter participants produced when watching TV Hosts was not affected by the joint effect of Pairs and Relationships. Given no effects were found, I did not further explore unshared or shared laughter duration.

3.4.2.2 Tom & Jerry

The duration of total laughter, shared laughter, and unshared laughter production in watching Tom & Jerry videos was analysed separately. The results of total laughter duration showed a significant main effect of Pairs, $F(1,74) = 10.259$, $p = .002$, $\eta_p^2 = .122$, indicating NA dyads (M = 14.914sec, SEM = 1.763ses) produced significantly more laughter than Mixed dyads (M = 5.994sec, SEM = 2.156ses) in watching Tom & Jerry videos; and a significant main effect of Relationship, $F(1,74) = 20.794$, $p < .001$, $\eta_p^2 = .219$, indicating that participants produced significantly more laughter in watching Tom & Jerry when with a Friend (M = 16.804sec, SEM = 2.443sec) than with a

Stranger (M = 4.105sec, SEM = 1.338ses). Additionally, there was a significant interaction between Pairs x Relationship, $F(1,74) = 9.906$, $p = .002$, $\eta_p^2 = .118$, indicating that the amount of laughter produced by NA and Mixed dyads was affected by Relationship closeness.

Post Hoc analysis using independent t-tests found that NA Friends produced significantly more laughter than NA Strangers while watching Tom & Jerry, $t(11.516) = 3.490$, $p = .005 < 0.01$. However, NA Friends produced a similar amount of laughter as Mixed Friends, $t(17) = 2.015$, $p = .060$; and Mixed Friends produced a similar amount of laughter as Mixed Strangers, $t(35) = 1.174$, $p = .248$; and NA Strangers produced a similar amount of laughter as Mixed Strangers, $t(57) = .100$, $p = .921$. The significance level was adjusted using Bonferroni correction for 4 comparisons ($p = .0125$). These findings suggested that the relationship closeness has an impact on the amount of laughter produced in NA dyads but not in Mixed dyads during watching Tom & Jerry: NA participants produced more laughter when they interacted with a Friend than with a Stranger. However, there was no difference in the amount of laughter Mixed dyads produced; regardless, they were watching Tom & Jerry with a Friend or with a Stranger.

The same pattern of results was found in the analysis of the duration of Shared and Unshared laughter as with Total laughter (see Appendix 3A). Together, these findings suggest that relationship closeness has an impact on the amount of shared and unshared laughter produced in NA dyads but not in Mixed dyads whilst watching Tom & Jerry: NA participants produced a greater amount of shared and unshared laughter when they interacted with a Friend than with a Stranger. However, there was no difference in the amount of shared and unshared laughter Mixed dyads produced no matter when they were watching Tom & Jerry with a Friend or with a Stranger.

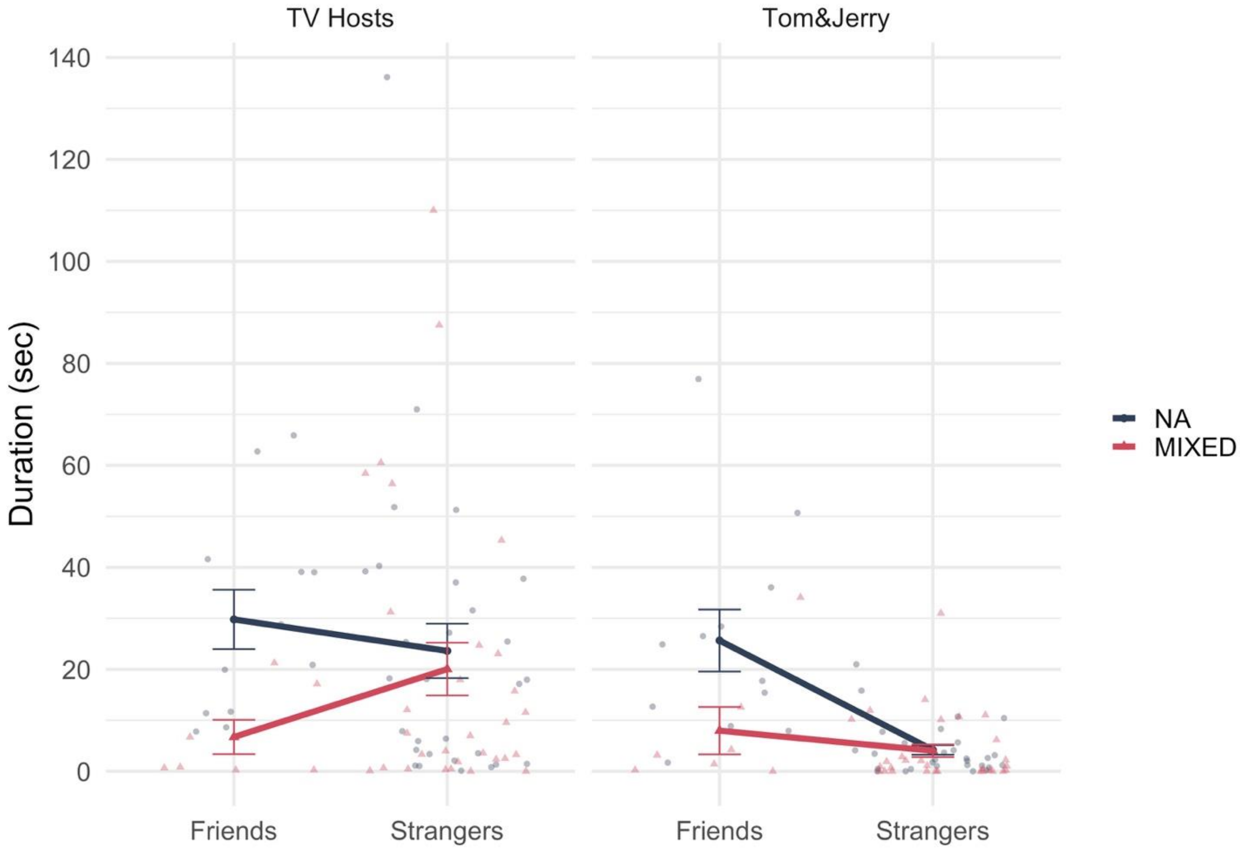


Figure 3.6 The duration of total laughter production in video watching task

Note. Each dot represents the duration of one dyad's laughter production. Each dark colour line represents the average duration of laughter production across either Non-autistic or Mixed dyads in Friends and Strangers. Error bars: ± 1 SE.

3.5 Discussion

The current study aimed to investigate whether the closeness of relationships (Friends/Strangers) would influence laughter behaviour between pairs of one autistic and one non-autistic adult (Mixed dyads) and pairs of two non-autistic adults (NA dyads) during a naturalistic, unstructured conversation task and a funny video-watching task. Overall, the results were in line with our hypotheses. Regardless of the closeness of the relationship, Mixed dyads produced significantly less laughter than

NA dyads in both the conversation task and the video-watching task. In addition, relationship closeness only affects laughter production in NA dyads, whilst the amount of laughter in Mixed dyads did not differ when interacting with either their friend or a stranger. These findings may indicate that autistic adults show a different pattern of laughter production relative to non-autistic adults during social communication.

3.5.1 Effect of task types on laughter production

Generally, all dyads produced more laughter (Total laughter) and laughed together more often (Shared laughter) during video watching than when in conversation. However, this effect of Task types was not found in the production of Unshared laughter. It is important to note that participants laughed (Total laughter) around 1.5 times more during the video-watching task than during the conversation task, and strikingly, participants laughed together (Shared laughter) around 2 times more during the video-watching task than during the conversation task. It was this tendency of Shared laughter; therefore that led to the difference in Task types on the Total laughter observed. Although our main interest is not exploring the effect of Task types on laughter production, however, previous studies found that participants laughed significantly more when watching funny videos in the presence of a laughing partner (Addyman et al., 2018; Weber & Quiring, 2017). It could be a result of the contagious-laughter effect on the production of Shared laughter: one partner laughs involuntarily because of the funny videos, and then the second one laughs contagiously while hearing the laughter, even if they do not find anything funny. Therefore, it is not surprising that all participants produced more shared laughter during the videos when their partner was laughing with them.

Interestingly, the amount of Unshared laughter is comparable between the two tasks. It is unclear from previous literature on the exact function of unshared laughter in social interaction, and researchers have defined unshared laughter in various different ways (Hudenko et al., 2009; Kashdan et al., 2014a; KURTZ & ALGOE, 2015). A study on autistic children found that they seem to be more likely to express unshared laughter, and thus interpreted unshared laughter as primarily in response to positive internal states, rather than the kind of laughter used as an exchanging signal in social interactions (Hudenko et al., 2009)Although the analysis on the dyadic level does not provide interpretation on the individual level, it is clear that the nature of Shared laughter is distinct from that of Unshared laughter in our results. Unshared laughter could be a reflection of one's internal states and thus less influenced by external situations, whereas Shared laughter is strongly affected by a contagious-laughter effect in video-watching tasks; in other words, serving as a social signal, it is strongly mediated by social context (i.e., the presence of a laughing partner) and external humour stimuli (i.e., funny videos).

3.5.2 Effect of pairings on laughter production

As predicted, our results showed that Mixed dyads produced less Total, Shared and Unshared laughter compared to NA dyads in both conversation and video-watching tasks. This same pattern was seen for both shared laughter and unshared laughter, indicating that both contributed to the difference between pair types in the total laughter observed.

Similar to previous laughter studies (KURTZ & ALGOE, 2015; Smoski & Bachorowski, 2003), I considered shared laughter as both contagious laughter and a communicative signal for joining in the other. Our finding that Mixed dyads produced less shared laughter than NA dyads is consistent with the previous finding that showed reduced contagious laughter in autistic children (Helt et al., 2020; Helt & Fein, 2016a). Contagious laughter is brought about primarily by automatic mimicry (Hatfield et al., 2014); indeed, a reduction in automatic facial expression mimicry in autistic individuals was found in previous studies (McIntosh et al., 2006; Yoshimura et al., 2015). One possible explanation for our results is that autistic participants engaged in a lesser degree of automatic mimicry during social interaction. As a consequence, they may join in with laughter and mimic others' laughter less during an interaction. Also, autistic individuals have been found to laugh in response to social events and to use laughter as a social communicative exchange signal more rarely relative to their non-autistic peers (Auburn & Pollock, 2013; Bauminger et al., 2008; Helt & Fein, 2016a; Hudenko et al., 2009; Reddy et al., 2002). Therefore, the current findings may be due to autistic adults having a different pattern of laughter production relative to non-autistic adults during social communication.

An alternative explanation is that the results reflect a mismatch between autistic and non-autistic communication styles. Indeed, Sasson et al. (2017) found that non-autistic adults judged autistic individuals unfavourably, as more awkward, less approachable and as someone they were less likely to become friends with, and this judgement was formed rapidly after brief video and/or audio clips were presented and persisted even after long exposure. It was further noted that these judgements were not based on the content of the stimuli (from the transcript of speech), but based on the social presentation and style of autistic individuals, including non-verbal cues like prosody and facial expression (Sasson et al., 2017). As research shows that facial mimicry and frequency of laughing together reflect the desire for further affiliation and relationship development in non-autistic adults (Kashdan et al., 2014b; Treger et al., 2013), non-autistic adults were probably less motivated to display pro-social behaviours such as laughter in Mixed dyads. In the future, it is worth extending the current project by analysing the individuals separately in terms of the amount of laughter and see if NA adults produce less laughter in Mixed dyads, or if it's just the autistic adults who produce less.

3.5.3 Effect of relational closeness on laughter production

Across the analyses of Total, Shared and Unshared laughter, we detected significant interaction effects. Interestingly, our results indicated that relationship closeness influenced laughter production among NA dyads. However, no such effect was found among Mixed dyads. Specifically, NA Friends produced more Unshared laughter and Shared laughter than NA Strangers regardless of Task types; and NA Friends produced more Total laughter than NA Strangers only in Video watching task. Although there is a tendency for NA Friends produced more Total laughter than NA Strangers in conversation, however, this difference was not statistically significant.

In contrast, previous studies found no difference in overall laughter production between neurotypical strangers and friends in watching funny videos or conversation (Devereux & Ginsburg, 2001; Ramírez-Esparza et al., 2019; Vettin & Todt, 2004). Our results replicated previous studies that showed that longer laughter duration, especially shared laughter duration, has been found in neurotypical dyads of friends and romantic partners (KURTZ & ALGOE, 2015; Smoski & Bachorowski, 2003). It is possible that both spontaneous and contagious laughter contributed to the increased laughter in NA Friends. On the one hand, friends who shared more past experience and mutual knowledge, may acknowledge clips in the video-watching task similarly as humorous and laughable. Indeed, friends grow to appreciate similar humour styles (Hunter et al., 2016) and sharing a sense of humour is one of the most important friend traits (Curry & Dunbar, 2013). On the other hand, as proposed by Smoski & Bachorowski (2003), distinctive laughter acoustics of friends may be repeatedly associated with past positive experiences, leading to a heightened contagious laughter response. Helt et al. (2020) also found NT children did tend to laugh more contagiously with familiar person stimuli compared to unfamiliar person stimuli. This aforementioned evidence could also explain why we found NA Friends produced more Total laughter than NA Strangers only during funny video watching but not in conversation, as they shared the same sense of humour and thus laughed involuntarily together. However, laughter is predominately acting as a communicative tool in conversation, it helps people to establish and maintain the relationship (Scott et al., 2014). Compared to Strangers, Friends are very familiar with each other, and they already form a stronger social bond, so they are less motivated to produce a great amount of voluntary/conversational laughter in order to establish and enhance the relationship with the other. In contrast, NA Strangers show the opposite pattern of laughter production in both tasks; perhaps the lack of common sense of humour resulted in less laughter in video watching, but NA strangers were more motivated to utilise the social functions of laughter (e.g., showing politeness, agreement and affiliation) to form and enhance the relationship and social bonding, and therefore more frequently laughed voluntarily in conversation (Provine, 1993; Vettin & Todt, 2004). Together, our findings further support the idea that laughter is strongly mediated by social context (Scott et al., 2014): people laugh more often when interacting with familiar people, and shared laughter is an indication of or perhaps of a desire for relational closeness and affiliation (KURTZ & ALGOE, 2015; Kurtz & Algoe, 2017).

Unlike NA dyads, no such relationship closeness effect was found on the production of Total laughter, Shared laughter or Unshared laughter in MIXED dyads, neither in conversation nor video watching. Friendship quality is commonly reported to be poorer in autistic friendships (Petrina et al., 2014; Sedgewick et al., 2019). Although these findings are in line with our hypothesis, relationship quality and friendship history were surprisingly matched between Mixed and NA dyads, which is instead consistent with previous reports of comparable communication styles and positive affect displays in Mixed friendship and NA friendship (Bauminger et al., 2008). Previous research found that autistic children produced enhanced contagious laughter when watching videos in which their parents served as stimuli (Helt et al., 2020). However, in our study, we asked autistic adults to interact face-to-face with a familiar person, which is very different from watching videos of that same person. We found no difference in laughter production between Mixed Friends and Mixed Strangers. A similar study also found autistic children showed no significant difference in reported positive affect when watching funny cartoons with a parent/friend or watching them alone (Helt et al., 2016). Previous studies also indicated that autistic individuals showed diminished emotional contagion and were less likely to laugh in response to social events compared to their non-autistic peers (Helt & Fein, 2016a; Reddy et al., 2002); therefore, autistic adults may have a different pattern regarding producing laughter and reacting to laughter in interaction. Their performance seems to be highly dependent upon the circumstance (Helt et al., 2020). They may generally laugh voluntarily less and use it less as a communicative tool compared to non-autistic adults. In addition, they may not perceive the funny videos as having the same funniness level as their non-autistic peers; as a result, they produce less involuntary laughter whether watching a video with a Friend or a Stranger. It should be acknowledged that the number of Friends pairs, especially in Mixed dyads, was relatively small compared to Strangers pairs; hence, it is possible that the analysis might be underpowered in detecting an effect of relationship closeness on laughter production.

3.5.4 Difference between laughter production in video watching

In the follow-up analysis of the video-watching task, I found that dyads generally produced a comparable amount of laughter while watching funny videos about TV Hosts containing contagious laugh; also, relationship closeness did not affect the dyads on laughter production. Surprisingly, we found relationship closeness has an impact on Total, Shared and Unshared laughter production only in NA dyads while watching funny videos about Tom & Jerry. In particular, NA Friends produced a greater amount of laughter than NA Strangers when watching Tom & Jerry. However, the amount of laughter produced by Mixed dyads is not affected by relationship closeness. Mixed Friends and Mixed Strangers produced a comparable amount of laughter when watching Tom & Jerry.

Though we predicted that NA dyads would laugh more with a Friend than a Stranger, and Mixed dyads would not be as affected by relationship closeness as NA dyads, it is somehow interesting that we only got the effect on the Tom & Jerry videos but not with the TV Hosts' videos. Because both NA and Mixed dyads laughed overall more to the TV hosts videos than Tom & Jerry cartoon, one explanation is that funny videos about TV hosts laughing uncontrollably were too funny to the participants; therefore, we failed to detect an effect of relationship closeness on laughter production due to ceiling effect. However, we intentionally selected Tom & Jerry (a classic slapstick cartoon) as video stimuli to enhance laughter production in autistic individuals, as previous research demonstrated that autistic individuals enjoy slapstick humour (Weiss et al., 2013). Surprisingly, our results from Tom & Jerry showed the opposite: NA Friends laughed significantly more than NA Strangers, but no difference was found between Mixed Friends and Mixed Strangers. This replicates the findings of a previous study in which autistic children show greater reported positive affect while watching Tom & Jerry with a companion (a parent or a friend) than watching it alone (though the results were not significant). However, autistic children were less likely to laugh synchronously (at the same time) or contagiously (within 2 s) with their companion than their non-autistic peers (Helt et al., 2016). This could explain why we found a tendency for Mixed Friends to laugh more than Mixed Strangers, but this difference was not statistically significant.

There are multiple factors that limit the interpretability of the current work. Firstly, regarding our sample, the groups were not matched on age and gender. Although individuals were assigned into dyads such that the age difference between dyadic partners and the ratio of same-to-mixed-sex were matched between dyad types, participants in Mixed dyads on average were still older than in NA dyads. Secondly, it is worth noting that autistic participants scored higher on depressive symptoms and alexithymia than NA participants. In particular, emotion recognition and spontaneous facial expression production were recently found to be associated with alexithymia in both autistic and non-autistic participants (Keating & Cook, 2020; Trevisan et al., 2018), therefore it is possible that the observed differences between groups may reflect the effect of alexithymia instead of autism. As alexithymia is a common co-occurrence in about 50% of autistic individuals (Poquérusse et al., 2018), further analysis should consider it as a covariate to account for potential confounds (Jarrold & Brock, 2004).

The current analysis served as a preliminary step for the future investigation of laughter behaviour in autistic adults. The experimental data can certainly be further analysed and explored. For instance, the current analysis was only based on the dyadic level, instead of the individual level, rendering the group-based explanation largely speculative. Since it is well recognized that both social partners act and are acted upon in dyadic interaction, the future multilevel analysis could consider modelling factors on an individual level to examine the participant-based outcomes (e.g., individual laughter duration, the latency of laughter response, etc.) and their relationship with participants' characteristics (e.g., diagnostics, gender, BDI and TAS score). These further explorations on the matter may provide more illuminating findings about laughter behaviour and social communication in autistic and NA participants. However, the above-suggested future exploration is outside the scope of the current PhD thesis and could instead be future work for my postdoctoral period.

Unfortunately, we did not include autistic and autistic dyads in our current work due to the small number of dyads recruited (Stranger: n = 4; Friend: n = 2).

Nevertheless, it would be interesting for future research to explore laughter behaviour among autistic dyads, especially in autistic and autistic Friends, where different communicative styles (Bauminger et al., 2008) and more positive and supportive experiences have been reported (Crompton et al., 2020).

3.6 Conclusion

In summary, these results reveal autistic adults show a different pattern of laughter production relative to non-autistic adults during social communication. Non-autistic adults paired with other non-autistic adults (NA dyads) produced more laughter in Friend pairs than in Stranger pairs. In contrast, autistic adults paired with non-autistic adults (Mixed dyads) generally used laughter less as a communicative signal during social interaction, and the amount of laughter they produced was less influenced by the closeness of the relationship. However, it is also possible that our results reflect a mismatch between autistic and non-autistic communication, and specifically in existing friendships, may have resulted in patterns of laughter more akin to that seen between strangers.

3.7 Appendix 3A

Tom & Jerry

Shared Laughter

The results of shared laughter duration showed a significant main effect of Pairs, $F(1,74) = 6.345$, $p = .014$, $\eta_p^2 = .079$, indicating NA dyads (M = 10.438sec, SEM = 1.670ses) produced significantly more shared laughter than Mixed dyads (M = 3.675sec, SEM = 2.079ses) in watching Tom & Jerry videos; and a significant main effect of Relationship, $F(1,74) = 13.834$, $p < .001$, $\eta_p^2 = .157$, indicating that participants produced significantly more shared laughter in watching Tom & Jerry when with a Friend (M = 12.050sec, SEM = 2.355sec) than with a Stranger (M = 2.063sec, SEM = 1.290ses). Additionally, there was a significant interaction between Pairs x Relationship, $F(1,74) = 6.498$, $p = .013$, $\eta_p^2 = .081$, indicating that the amount of shared laughter produced by NA and Mixed dyads was affected by Relationship closeness.

Post Hoc analysis indicated that NA Friends produced significantly more shared laughter than NA Strangers while watching Tom & Jerry, $t(39) = 4.129$, $p = < .001$. However, NA Friends produced a similar amount of shared laughter as Mixed Friends, $t(17) = 1.534$, $p = .243$; and Mixed Friends produced a similar amount of shared laughter as Mixed Strangers, $t(35) = .609$, $p = .546$; and NA Strangers produced a similar amount of shared laughter as Mixed Strangers, $t(57) = -.065$, $p = .949$. The significance level was adjusted using Bonferroni correction for 4 comparisons (p = .0125).

Unshared Laughter

The results of unshared laughter duration showed a significant main effect of Pairs, $F(1,74) = 7.957$, $p = .006$, $\eta_p^2 = .097$, indicating NA dyads (M = 4.477sec, SEM

= .484ses) produced significantly more unshared laughter than Mixed dyads (*M* = 2.320sec, *SEM* = .592ses) in watching Tom & Jerry videos; and a significant main effect of Relationship, $F(1,74) = 12.592$, $p < .001$, $\eta_p^2 = .145$, indicating that participants produced significantly more unshared laughter in watching Tom & Jerry when with a Friend (*M* = 4.755sec, *SEM* = .671sec) than with a Stranger (*M* = 2.042sec, *SEM* = .367ses). Additionally, there was a significant interaction between Pairs x Relationship, $F(1,74) = 6.315$, $p = .014$, $\eta_p^2 = .079$, indicating that the amount of unshared laughter produced by NA and Mixed dyads was affected by Relationship closeness.

Post Hoc analysis using independent t-tests found that NA Friends produced significantly more unshared laughter than NA Strangers while watching Tom & Jerry, $t(39) = 5.302$, $p = < .001$. However, NA Friends produced a similar amount of unshared laughter as Mixed Friends, $t(17) = 2.546$, $p = .021$; and Mixed Friends produced a similar amount of unshared laughter as Mixed Strangers, $t(35) = .609$, $p = .546$; and NA Strangers produced a similar amount of unshared laughter as Mixed Strangers, $t(57) = .343$, $p = .733$. The significance level was adjusted using Bonferroni correction for 4 comparisons ($p = .0125$).

Chapter 4. Explicit Rating on Perceptual Affective Properties

4.1 Abstract

Acting as salient communicative signals, genuine (spontaneous) and posed (social) laughter are distinct in acoustic features and perceptual affective properties; additionally, they recruit different neural systems during perception. To extend our understanding of laughter perception in autism, we asked autistic and non-autistic adults (comparable for age, gender and IQ) to rate the authenticity, contagion valence and arousal of a range of genuine and posed laughter samples. Both autistic (Autism; n=25) and non-autistic (NA; n=25) adults were able to discriminate between genuine and posed laughter. Interestingly, autistic adults rated posed laughter as more authentic, more positive and causing more emotional arousal than their non-autistic peers did, and hence to be more similar to genuine laughter. These findings suggest that autistic adults can discriminate between genuine and posed laughter, but judge posed laughter to be more like genuine laughter than non-autistic adults. In summary, there are subtle differences between autistic and non-autistic adults in differentiating the authenticity of laughter and perceiving its affective properties; but importantly, reduced discrimination means that autistic adults perceive posed laughter more generously.

4.2 Introduction

As stated in Chapter 1, laughter has long been viewed as a genuine and uncontrolled emotional vocalisation in response to amusement and humour. However, laughter predominately exists in human conversation: people frequently laugh after verbal utterances during communication as signalling agreement, liking and affiliation

(Gervais & Wilson, 2005; Todt & Vettin, 2005; Vettin & Todt, 2004). Similar to the functional distinctions in the production of smiles, based on the recruitment of facial muscle units, it could occur automatically as a genuine 'Duchenne display' or under greater performer controls as a posed 'Non-Duchenne display' (Ekman et al., 1990; Gervais & Wilson, 2005; Ruch & Ekman, 2001; Wild et al., 2003). Laughter signal itself varies in the degree of volitional control, emotional content, and authenticity (Chen, 2018; Lavan et al., 2016; McGettigan et al., 2015; Scott et al., 2014); it can be either driven by external stimuli, which are strongly linked to emotional arousal and reflects one's internal states (genuine, spontaneous, involuntary laughter): we laugh uncontrollable to express joy and happiness; or it can be a self-controlled act, which is used as a social signal during interactions (posed, deliberate, volitional laughter): we laugh deliberately to pass on social meaning and intention (Gervais and Wilson, 2005; Wild et al., 2003).

It has been evident that genuine, spontaneous, and posed, volitional laughter is acoustically distinct. Moreover, the difference in acoustic features influences people's perceptual judgement of its affective properties (Bryant & Aktipis, 2014; Lavan et al., 2016; McGettigan et al., 2015). Furthermore, the authenticity of vocal signals affects acoustic and perceptual profiles of genuine and social laughter, and such leads to processing differences in the neural pathway (Lavan et al., 2017; McGettigan et al., 2015; O'Nions et al., 2017; Scott et al., 2014; Warren et al., 2006; Wild et al., 2003).

Bryant & Aktipis (2014) selected spontaneous laughs from conversations between female friends, while volitional laughs were selected from a separate group of females producing laughter on demand in a neutral reading recording. Using principal component analysis on acoustic properties, they found spontaneous laughter has a higher average pitch (F0 mean), higher maximum pitch (F0 max), and a higher rate of intervoicing intervals per call (rate of IVI) than volitional laughter. In the following experiments of perceptual judgement, 1) participants performed above-chance accuracy in judging the authenticity of laughter in a forced choice task labelling each stimulus as ‘real’ or ‘fake’; 2) when laughs were sped up, both sped-up spontaneous laughter and sped-up volitional laughter were judged as more ‘real’; and 3) when laughs were slowed down, slow volitional laughter could be identified as human-made at the above-chance level (Bryant & Aktipis, 2014). However, slow spontaneous laughter was hard to be identified as produced by humans or animals. These findings suggest that the acoustic properties of spontaneous and volitional laughter would affect its perceptual judgement. As an authentic signal, the nature of spontaneous laughter has harder to fake acoustic features in contrast to volitional laughter.

However, spontaneous laughter in Bryant & Aktipis's (2014) study was selected from the conversation, with considerable conversational laughter produced under voluntary control. To further examine the difference between involuntary/spontaneous/authentic and voluntary/deliberate/posed laughter. Lavan et al. (2016) compared the acoustic profile of spontaneous, authentic laughter in response to humour videos with volitional, fake laughter produced under full voluntary control. Spontaneous laughter has a higher pitch, longer duration, and different spectral characteristics in comparison with volitional laughter. They further explored the relationship between acoustic features and participants’ ratings of its perceived affective properties and physiological characteristics. Results indicated perceptual difference exists between spontaneous laughter and volitional laughter: spontaneous laughter was perceived as significantly more exciting and intense (arousal), more positive (valence), and categorised as ‘real’ (authenticity) than volitional laughter. Also, acoustic measures of laughter type could predict participants’ perceptual ratings: total duration, F0 mean, and spectral centre of gravity predominant predicted ratings for spontaneous laughs, while harmonics-to-noise ratio (HNR) not only predicted but also significant negative correlated to affective ratings for volitional laughs. In addition, volitional laughter was rated as significantly more nasal than spontaneous laughter by phonetically trained listeners, furthermore, HNR significantly negatively correlated to physiological characteristics (Lavan et al., 2016).

Laughter stimuli generated in a similar process showed the same acoustic profile in McGettigan et al. (2015)'s study, with evoked, spontaneous, authentic laughter having significantly higher pitch measures than emitted, volitional, deliberate laughter. Differences in perceived affective properties were found, where spontaneous laughter was perceived as significantly more emotionally intense, significantly more emotional and behavioural contagious, significantly more positively valenced and marginally more arousing than volitional laughter. Furthermore, neurotypical adults showed greater activation in the anterior medial prefrontal cortex (amPFC), anterior cingulate gyrus, and left thalamus when passive listening to volitional laughter than spontaneous laughter, which indicated 'an obligatory attempt to determine others' mental states' (McGettigan et al., 2015, p. 254) during the perception of voluntary laughter. These activations from medial prefrontal and sensorimotor regions suggest that laughter perception automatically engages people's high-level cognitive skills, such as mentalising ability, to understand and interpret the intention and meaning behind laughter (McGettigan et al., 2015).

Taking all the evidence above into account, the authenticity of laughter forms different acoustic and perceptual profiles of genuine and posed laughter, moreover, understanding the social meaning and intention behind the laughter is crucial for individuals using and responding to this social signal in forming relationships and maintaining social bonds (R. Dunbar & Mehu, 2008; Scott et al., 2014). Therefore, autistic people are very likely to experience a different pattern of laughter processing in daily interaction due to their difficulty in mentalising ability (Baron-Cohen et al., 1985; U. Frith, 2001).

Only a few studies have researched laughter in the autistic population, and most have looked at the difference in laughter production among autistic children (Helt & Fein, 2016b; Hudenko et al., 2009). Hudenko et al. (2009) found acoustic differences in laughter produced by typically developing and autistic children. Autistic children produce primarily ‘‘voiced’’ laughter but display relatively little “unvoiced laughter” during social play. A follow-up study indicated that the ‘‘voiced’’ laughter produced by autistic children is perceived as more positive affective feelings by neurotypical adults (Hudenko & Magenheimer, 2012). However, no studies have been researching laughter perception in autistic adults and whether they have a different perceptual pattern relative to neurotypical adults. Also, it is unclear whether the authenticity of laughter would affect the perceived affective properties of genuine and posed laughs.

4.2.1 The present study

In this study, we asked autistic and non-autistic adults (comparable for age, gender and IQ) to rate the perceptual affective properties — authenticity, contagion valence and arousal of a range of genuine and social laughter samples. We hypothesised that autistic adults would show a different pattern of perceptual judgement relative to neurotypical adults, specifically, they would have difficulty differentiating between genuine and social laughter relative to neurotypical adults. Furthermore, we investigated whether the authenticity of laughter modulates these perceptual differences.

4.3 Method

4.3.1 Participants

In total, 26 autistic adults (five females) and 27 non-autistic (NA) adults (7 females) took part in this study. The groups were comparable for gender ($\chi^2(1) = .339$, $p = .56$), age ($t(51) = -.928$, $p = .358$), and verbal ($t(51) = .727$, $p = .471$) and performance ($t(51) = 1.026$, $p = .310$) IQ, as measured by either the Wechsler Adult Intelligence Scale (WAIS-III UK; Wechsler, 1999a) or Wechsler Abbreviated Scale of Intelligence (WASI-II, Wechsler, 1999b). All participants in the neurotypical group and 25 participants in the autism group completed the Autism-Spectrum Quotient (AQ; Baron-Cohen rt al., 2001), a 50-item self-assessment questionnaire examining autistic traits, the groups differed on AQ, $t(50) = -9.537$, $p < 0.001$ (See Table 4-1).

All participants in the autism group had a diagnosis of autism spectrum disorder ($n = 5$) or Asperger syndrome ($n = 21$) from a qualified clinician, with 12% reporting an additional diagnosis of another developmental disorders: dyslexia ($n = 1$), ADHD ($n = 1$) and dyspraxia ($n = 1$). The Autism Diagnostic Observation Schedule (ADOS) (Hus & Lord, 2014) was administered to verify the diagnosis. In total, 10 participants met the criteria for autism and 11 more for autism spectrum on the ADOS classification. The remaining five scored below the threshold but were retained within the sample because they reported significant social difficulties in everyday life on the AQ and showed symptoms on the ADOS, albeit subthreshold. Furthermore, three of them had an AQ score above the recommended cut-off of 32. Informed written consent was obtained prior to testing, and the project received approval from the UCL research ethics committee.

However, three participants (1 from the Autism group, 2 from the NA group) were excluded from further analysis as they were considered outliers (see the results section for a detailed description of exclusion criteria). The groups remained comparable on gender ($\chi^2(1) = .439$, $p = .508$), age ($t(48) = -.525$, $p = .602$) and verbal ($t(48) = 1.196$, $p = .237$) and performance ($t(48) = 1.487$, $p = .143$) IQ after excluding these participants and, likewise, they still differed on the AQ, $t(47) = -9.819$, $p < .001$. Full details of the groups are given in Table 4-1.

Table 4-1 Details of the participants included in the analysis of data

			Explicit Rating of Laughter	
	Autism group	NA group	Autism group	NA group
N (male:female)	26 (21:5)	27(20:7)	25 (20:5)	25 (18:7)
Age (years)	34.885 (7.706)	32.481 (10.814)	34.680 (7.793)	33.280 (10.826)
Verbal IQ	115.856 (10.130)	117.926 (10.684)	115.480 (10.162)	118.960 (10.406)
Performance IQ	110.538 (14.428)	114.481 (13.554)	110.200 (14.620)	116.000 (12.900)
AQ***, [a]	33.160 (8.740)	13.704 (5.777)	33.792(8.325)	13.880 (5.674)
ADOS_comm	3.308 (2.346)	N/A	3.320 (2.393)	N/A
ADOS_RSI	5.731 (2.393)	N/A	5.800 (2.415)	N/A
ADOS (total)	8.654 (3.382)	N/A	8.720 (3.434)	N/A

Note. Values are given as mean (standard deviation) except when otherwise stated. NA = non-autistic; AQ = autism-spectrum quotient. *** $p < 0.001$. [a] one autistic participant did not complete the AQ questionnaire

4.3.2 Materials

4.3.2.1 Laughter stimuli

The laughter stimuli (40 in total) consisted of 20 genuine (involuntary) and 20 posed (voluntary) laughter stimuli. The duration of each stimulus was edited and cut into complete laughter sound clips from 2 to 2.99 seconds (average duration = 2.51 seconds; *SD* = 0.36; range = 1.7 to 3.14 seconds). The laughter stimuli were selected from the emotional vocalisation dataset (100 in total) recorded from a previous study (see Chen, 2018).

Briefly stated, the laughter was generated by six adults who were not professional actors (aged between 23 to 46 years; 3 females) and recorded using professional equipment in a sound-proof, anechoic chamber at University College London. To elicit genuine laughter, each speaker viewed videos on a computer screen whilst wearing headphones, which had been identified beforehand as amusing to that participant (Lavan et al., 2016; McGettigan et al., 2015). The emotional experience was described positively by speakers during and after the recording session of genuine laughter. To produce posed laughter, speakers were asked to generate laughter "on demand" and fully under volitional control, without any external stimulation and in the absence of an underlying emotional state. Importantly, speakers were always asked to produce posed laughter before the genuine ones to avoid that positive emotional states associated with genuine laughter would affect the production of posed ones.

The raw audio files were downsampled at 44100 Hz to mono.wav files with 32-bit resolution. Individual files were prepared for each vocalisation from each speaker by visually identifying the onset and offset of each event in their oscillograms. All files were then normalised for root-mean-square (RMS) amplitude using the phonetic analysis software called PRAAT (Boersma & Weenink, 2014). In order to select the best examples from the genuine and posed laughter stimuli, a pilot perceptual validation experiment was conducted. Thirty native British speakers were asked to rate each stimulus on four different parameters (authenticity, emotion, frequency and control) using a 7-point Likert scale. Based on the results of the authenticity ratings ('Dose the sound reflect a genuinely-felt emotion?', 1 - signified posed, 7 - signified genuine), 20 genuine laughter stimuli with the most highly-rated authenticity rating (M = 5.80, SD = 0.45) and 20 posed laughter which received the lowest authenticity rating (M = 3.299, SD = 0.426) were selected from the original dataset (see Chen, 2018).

A range of acoustic parameters was extracted on laughter stimuli by using PRAAT (Boersma & Weenink, 2014). Independent t-tests indicated that genuine and posed laughter were significantly different in pitch (Mean pitch: genuine, M = 404.654 Hz, SD = 51.446, posed, M = 272.534 Hz, SD = 74.889, $t(34)=6.503$, $p < .001$; Median pitch: genuine, M = 401.454 Hz, SD = 64.841, posed, M = 259.307 Hz, SD = 74.591, $t(38) = 6.432$, $p < .001$), spectrum centre of gravity (Hz) (genuine, M = 1293.041 Hz, SD = 450.665, posed, M = 873.716 Hz, SD =272.458, $t(38) = 3.561$, $p = .001 < .01$), jitter (local) (genuine, M = 2.746 Hz, SD = .943, posed, M = 4.118 Hz, SD = .915, $t(38) = -4.672$, $p < .001$) and Mean harmonics-to-noise ratio (HNR) (genuine, M = 8.110, SD =2.627, posed, M = 6.121, SD = 2.007, $t(38) = 2.690$, $p < .001$). They were matched on duration (genuine, M = 2530 msec, SD = .385; posed, M = 2382 msec, SD = .362) and other measures — root-mean-square (RMS), intensity (dB), standard deviation of pitch (Hz), spectral standard deviation (Hz), fraction of locally unvoiced frames, and shimmer (local, dB).

4.3.2.2 Experimental design

Testing A 2 × 2 mixed design was implemented in which the type of laughter (genuine vs posed) constituted the within-subject variable, and the different groups of participants (Autism vs NA) constituted the between-subject factors.

All participants rated each laughter stimulus (40 in total) on four different 7-point Likert scales: Authenticity, Contagion, Valence, and Arousal. For the Authenticity ratings, participants rated the extent to which the laughter reflected a genuinely felt emotion (‘How much does the sound reflect a genuinely felt emotion?’ 1 - Not genuine, i.e. not genuine, sounds controlled, 7 - Extremely genuine, i.e. genuine, sounds uncontrolled). For the Contagion ratings, participants rated the extent to which the laughter made the listener feel an emotion (‘How much does hearing the sound make you feel like joining in and/or feeling the emotion?’ 1 - Not at all, i.e. it does not make me feel like joining in and/or feeling the emotion, 7- Extremely, i.e. it makes me feel like joining in and/or feeling the emotion). For the Valence ratings, participants rated the extent to which the laughter expressed a negative or positive emotion (‘How much does the sound reflect a positive or negative emotion?’ 1- Highly Negative, i.e. the person has the experience of extreme discomfort, 7- Highly Positive, i.e. the person has the experience of extreme pleasure). For the Arousal rating, participants rated the extent to which the laughter reflected emotional arousal (‘How much does the sound reflect emotional arousal?’ 1- Calm, i.e. the person who made this sound is feeling sleepy and with no energy, 7- Aroused, i.e. the person who made this sound is feeling alert and energetic). The four rating scales were implemented in separate blocks, each consisting of 20 genuine and 20 posed laughter stimuli. The order of laughter stimuli was randomised within each block. The Authenticity block was always presented first, followed by the remaining three blocks, which were counterbalanced across participants. This order of blocks was intended to encourage participants to rate laughter authenticity based on their first instinct rather than deliberate evaluation.

The task was delivered on a laptop using MATLAB software (version R2014a, Mathworks, Sherborn, MA, USA) with Psychtoolbox (Brainard 1997; Pelli 1997). Participants were asked to sit directly in front of the laptop and wear headphones (Sennheiser headphones HD 221) to ensure they were focused on the stimuli and to minimise external distractions. Once the laughter stimuli were presented through the headphones, participants were required to respond to each question as soon as possible. After each laughter stimulus offset, they had up to three seconds to give a response on the keyboard. To initiate the experiment, the task instruction was first displayed followed by a practice session with two laughter stimuli (one genuine and one posed laughter stimulus) rated on all four attributes. The practice and experimental sessions consisted of a total of 168 trials and took approximately 16 minutes.

4.3.3 Procedure

One experimenter administered testing in a testing room. At the beginning of testing, all participants were given a consent form to sign, that included a brief explanation of the study. The experimenter remained in the testing room throughout the test session. All participants were introduced to the experiment and asked to sit directly in front of the laptop and wear headphones. Before the test session started, each participant confirmed that he or she understood the task and had had the opportunity to ask any questions. At the conclusion of the testing, the experimenter asked whether participants had any further questions and gave them £7.5 per hour as payment for taking part in the study. Participants were also encouraged to contact the researchers if they had any further questions.

4.4 Results

To make our analysis more robust, firstly, we excluded outliers from our analyses. Considering our data is non-normally distributed, and we have a relatively small sample (see Figure 4.6 in Appendix 4A), we used the median absolute deviation from the median (MAD), which is more robust to detect outliers for non-normally distributed data and is immune to the sample size (Leys, Ley, Klein, Bernard, & Licata, 2013). As a criterion for detecting outliers, we used 3.5 MAD as a threshold suggested by previous analysis rather than the more common three MAD, as we intended to include as much data as possible (Leys et al., 2013). Using this method, one NA participant was detected as an outlier on two rating scales (Valence/Arousal), one NA participant was detected as an outlier on three rating scales (Authenticity/Contagion/Valence), and one autistic participant was detected as an outlier on one rating scale (Valence). Full details of outliers are given in Table 4-2. As a result, three outliers were removed for the entire analysis of the explicit rating task. Full background details of the reduced groups are given in Table 4-1.

Secondly, some participants failed to give ratings due to the 3-second time limit for each response. Therefore, participants who missed more than 16 out of 40 rating trials (40%) on any rating scale were considered not attending to the task fully and were excluded from further data analysis on this rating scale. On this basis, one autistic participant, who missed 19 stimuli on the valence rating scale, was excluded from the data analysis on the valence rating scale.

Table 4-2 Details of the number of outliers removed and the distance between outliers and the selected threshold

		Authenticity		**Contagion**		**Valence**		**Arousal**	
		Genuine	Posed	Genuine	Posed	Genuine	Posed	Genuine	Posed
NA	High	8.085	5.735	8.150	5.335	7.507	6.285	7.876	5.476
	N	-	-	-	-	-	-	-	-
	Low	3.415	1.065	2.250	0.665	4.39	1.615	3.724	1.324
	N	1	-	1	-	2	-	1	-
	Distance	0.965		0.95		2.44/1.04		1.024	
Autism	High	8.085	5.826	8.179	6.907	8.195	6.495	7.466	6.629
	N	-	-	-	-	-	-	-	-
	Low	3.415	1.674	2.471	-0.357	3.005	1.305	3.834	0.921
	N	-	-	-	-	1	-	-	-
	Distance					0.105			

Note. Genuine = Ratings for genuine laughter; Posed = Ratings for posed laughter; N = Number of outlier(s); High = Median + 3.5xMAD; Low = Median - 3.5xMAD; Distance = distance between outliers and the selected threshold.

4.4.1 Authenticity rating

A 2 x 2 mixed measures analysis of variance (ANOVA) was conducted for each rating scale (authenticity, contagion, valence and arousal), including the type of laughter (genuine vs posed) as the within-subject factor and participant group (Autism vs NA) as the between-subjects factor. Greenhouse-Geisser corrections were used, and p values were reported as two-tailed.

On the authenticity rating, there was a significant main effect on the type of laughter, $F[1,48] = 254.119$, $p < .001$, $\eta_p^2 = .841$, indicating that genuine laughter ($M = 5.593$, $SD = .696$, $SEM = .098$) was generally rated as more authentic than posed laughter ($M = 3.607$, $SD = .838$, $SEM = .119$). There was no significant main effect of the group, indicating that ratings of authenticity from autistic and non-autistic participants were similar, $F[1,48] = 3.656$, $p = .062$, $\eta_p^2 = .065$.

There was a significant interaction effect between laughter type and group, $F[1,48] = 6.261$, $p < .05$, $\eta_p^2 = .115$, indicating that authenticity ratings of different types of laughter differed between the non-autistic and autistic participants. The interaction graph (see Fig. 4) reveals that both non-autistic and autistic participants rated genuine laughter as more authentic than posed laughter. However, this tendency was more pronounced among non-autistic participants. This suggests that the non-autism group's authenticity ratings for laughter stimuli were more heavily influenced by its type (authenticity of laughter) than were those of the autism group. An independent samples t-test was conducted on genuine and posed laughter between the groups. The results show that the non-autism group ($M = 3.289$, $SD = .791$, $SEM = .158$) rated posed laughter significantly lower (less authentic) than did the autism group ($M = 3.925$, $SD = .773$, $SEM = .155$), $t(48) = -2.874$, $p < .01$. However, there was no significant difference for ratings of genuine laughter between non-autistic ($M = 5.587$, $SD = .699$, *SEM* = .140) and autistic (*M* = 5.599, *SD* = .706, *SEM* = .141) participants, $t(48) = .006$, $p = .951$. See Figure 4.1.

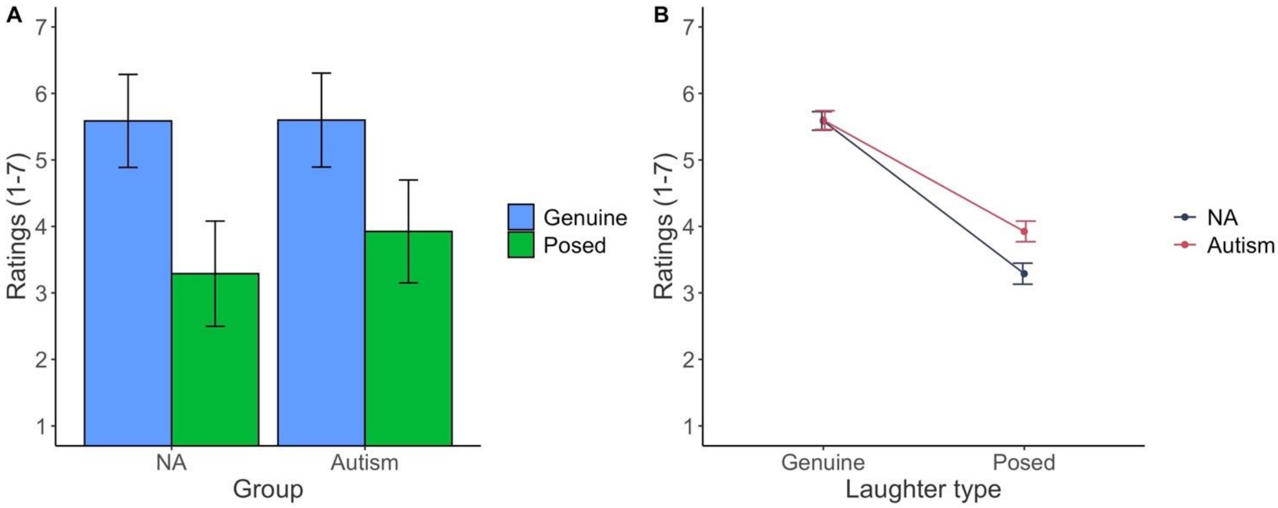


Figure 4.1 Authenticity rating

***Note.* Graph A: Average ratings for authenticity rating of laughter between Non-autistic and Autistic participants. Graph B: Interaction effect between the type of laughter stimuli and group. Error bars: ± 1 SD in A; ± 1 SE in B.**

4.4.2 Contagion rating

On contagion rating, there was a significant main effect of type of laughter, $F[1,48] = 234.712$, $p < .001$, $\eta_p^2 = .830$, indicating that genuine laughter (*M* = 5.129, *SD* = .855, *SEM* = .121) was generally rated as more contagious than posed laughter (*M* = 3.113, *SD* = .903, *SEM* = .128).

There was no significant main effect of group, $F[1,48] = .190$, $p = .665$, $\eta_p^2 = .004$, indicating that contagion ratings from autistic and non-autistic participants were similar.

There was no significant interaction effect between laughter type and group, $F[1,48] = 3.341$, $p = .074$, $\eta_p^2 = .065$, indicating that perceived genuine or posed laughter did not affect contagion ratings among autistic and non-autistic participants.

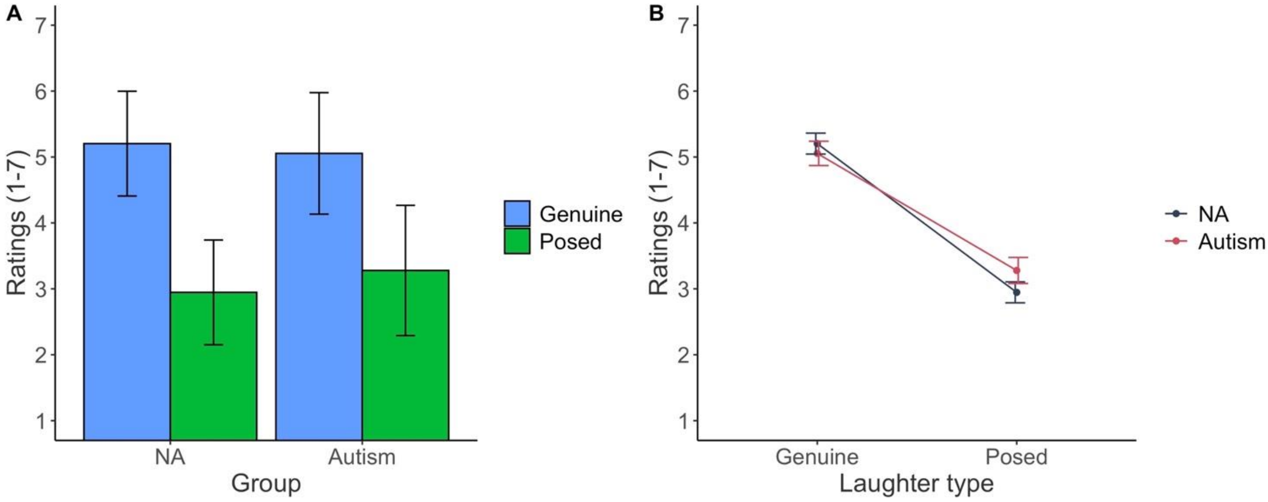


Figure 4.2 Contagion rating

***Note.* Graph A: Average ratings for contagion rating of laughter between Non-autistic and Autistic participants. Graph B: Interaction effect between the type of laughter stimuli and group. Error bars: ± 1 SD in A; ± 1 SE in B.**

4.4.3 Valence rating

On valence rating, there was a significant main effect of type of laughter, $F[1,47] = 214.942$, $p < .001$, $\eta_p^2 = .821$, indicating that the sound of genuine laughter (M = 5.718, SD = .524, SEM = .075) reflected a more positive emotion than the sound of posed laughter (M = 3.933, SD = .693, SEM = .099).

There was no significant main effect of group, $F[1,47] = 1.062$, $p = .308$, $\eta_p^2 = .022$, indicating valence ratings from autistic and non-autistic participants were similar.

There was no significant interaction effect between type and group, *F*[1,47] = 3.471, $p = .069$, $\eta_p^2 = .069$, indicating that perceived genuine laughter or posed laughter did not affect valence ratings among non-autistic and autistic participants.

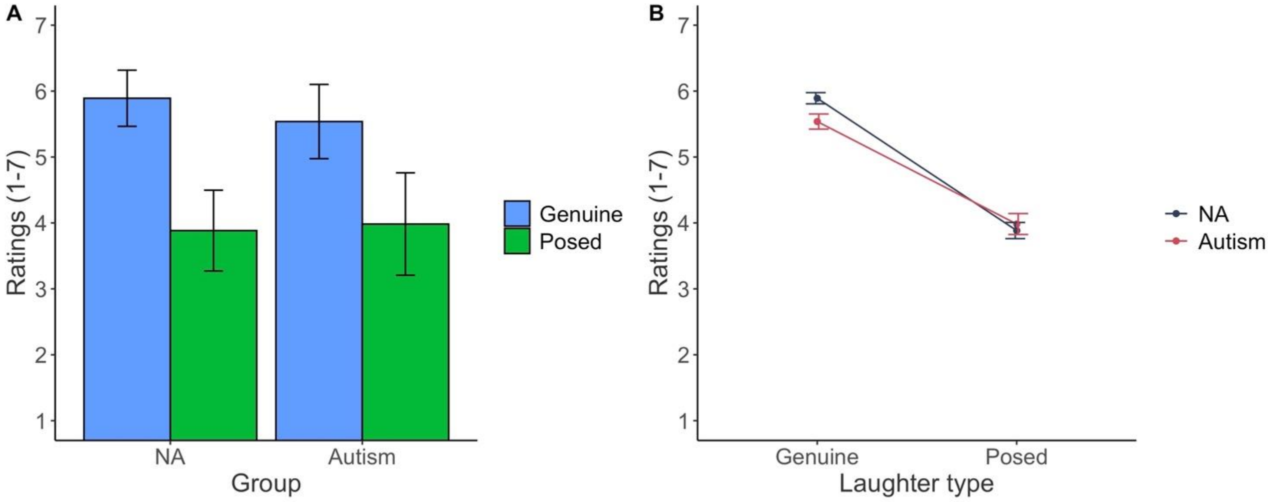


Figure 4.3 Valence rating

Note. Graph A: Average ratings for valence rating of laughter between Non-autistic and Autistic participants. Graph B: Interaction effect between the type of laughter stimuli and group. Error bars: ± 1 SD in A; ± 1 SE in B.

As we found borderline interactions in the valence rating, we then analysed the correlation between the ratings of authenticity and valence to explore the explanation of this effect. We found both ratings are highly correlated to laughter type, with a positive correlation between the authenticity rating of genuine laughter and the valence rating of genuine laughter, $r(48) = .528$, $p < .001$, and a positive correlation between the authenticity rating of posed laughter and the valence rating of posed laughter, $r(47) = .630$, $p < .001$. The fact that the results on the different scales correlated indicate that participants are doing similar ratings (showing similar rating pattern) on all the scales. Notably, the autism group had more similar results for the two ratings than the non-autism group. Participants with autism used the authenticity scale similar to the way they used the valence scale, which indicates that they generally performed less well in differentiating between genuine and posed laughter than non-autistic participants did across all scales (see Figure 4.4).

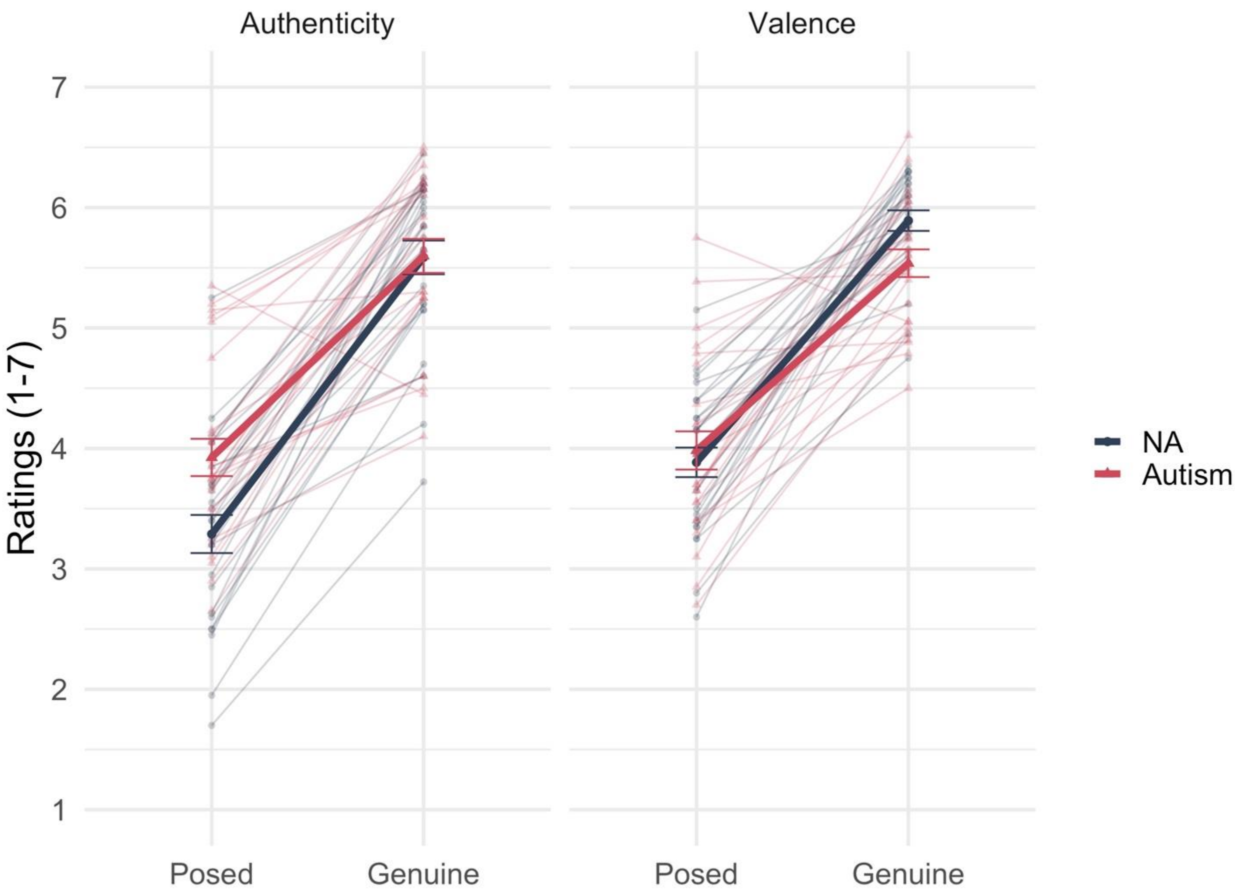


Figure 4.4 Comparison of ratings between authenticity and valence scales

Note. Each light colour line represents an individual's average ratings for posed and genuine laughter. Each dark colour line represents average ratings for authenticity and valence rating of laughter between Non-autistic and Autistic participants. Error bars: ± 1 SE.

4.4.4 Arousal rating

On the arousal rating, there was a significant main effect on the type of laughter, $F[1,48] = 360.197$, $p < .001$, $\eta_p^2 = .882$, indicating that the sound of genuine laughter ($M = 5.651$, $SD = .591$, $SEM = .084$) reflected stronger emotional arousal than the sound of posed laughter ($M = 3.594$, $SD = .768$, $SEM = .109$).

There was no significant main effect of the group, indicating that ratings on arousal from autistic and non-autistic participants were similar, $F[1,48] = 1.334$, $p = .254$, $\eta_p^2 = .027$.

There was a significant interaction effect between laughter type and group, $F[1,48] = 4.616$, $p < .05$, $\eta_p^2 = .088$, indicating that arousal ratings of different types of laughter differed between non-autistic and autistic participants. The interaction graph (see Figure 4.5) reveals that participants in both groups rated genuine laughter as more energetic and alert than posed laughter. However, this tendency was more pronounced among non-autistic participants. This suggests that the non-autism group's arousal ratings for laughter stimuli were more heavily influenced by its type (authenticity of laughter) than were those of the autism group. An independent t-test was conducted on genuine and posed laughter for both groups. The results show that the non-autism group ($M = 3.387$, $SD = .612$, $SEM = .123$) rated posed laughter lower (less emotional arousal) than did the autism group, with a borderline significant effect ($M = 3.801$, $SD = .860$, $SEM = .172$), $t(48) = -1.965$, $p = .055$. However, there was no significant difference in ratings of genuine laughter between non-autistic ($M = 5.676$, $SD = .596$, $SEM = .119$) and autistic ($M = 5.625$, $SD = .596$, $SEM = .119$) participants, $t(48) = .303$, $p = .763$.

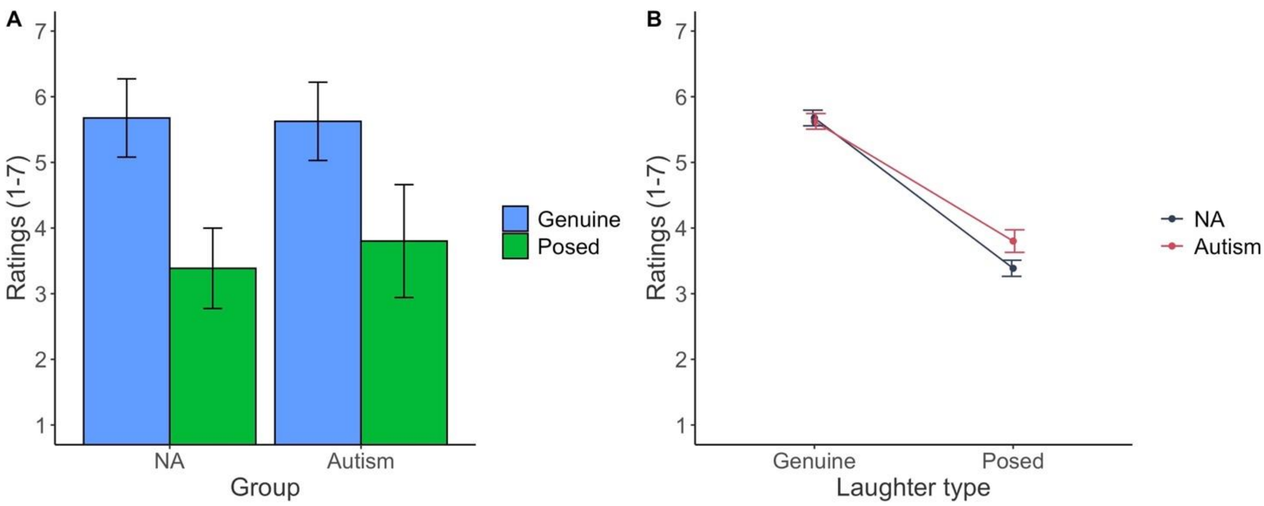


Figure 4.5 Arousal rating

Note. Graph A: Average ratings for arousal rating of laughter between Non-autistic and Autistic participants. Graph B: Interaction effect between the type of laughter stimuli and group. Error bars: ± 1 SD in A; ± 1 SE in B.

4.5 Discussion and Conclusion

The current study aims to investigate the perceptual difference between genuine and social laughter in autistic and non-autistic adults. Findings from the explicit ratings of perceptual affective properties suggest that autistic adults are able to differentiate between genuine and posed laughter, but to a lesser degree than non-autistic adults. In particular, there was no difference in the rating of contagion and valence scales between the groups, but autistic adults tend to perceive posed laughter as significantly more authentic and more emotionally arousing than non-autistic adults. In general, autistic adults with high IQs have subtle perceptual difficulties in explicitly processing laughter relative to their non-autistic peers.

Both Autism and NT groups rated genuine laughter as significantly more authentic, contagious, positive and emotionally arousing than posed laughter. These findings confirmed previous evidence that genuine (spontaneous, involuntary) laughter is perceived as more authentic than posed (deliberate, volitional) laughter in neurotypical adults (Chen, 2018; Lavan et al., 2016; McGettigan et al., 2015). Additionally, the authenticity of laughter affects people's perceptual judgement of its affective properties — genuine laughter was perceived as more intense, more arousing, more positive, and more emotional and behavioural contagious than posed laughter (Lavan et al., 2016, 2017; McGettigan et al., 2015)and the similar perpetual pattern has been found across the life span (Chen, 2018). Our current findings extend our knowledge to the autistic population: autistic adults experience perceptual differences between genuine laughter and posed laughter like their non-autistic peers.

Intriguingly, autistic adults found posed laughter significantly more authentic and emotionally arousing than non-autistic adults. These findings support our hypothesis that autistic adults have some degree of perceptual difference in differentiating the authenticity of laughter. It has been evident that autistic people show different patterns of the perception and production of social behaviours relative to their non-autistic peers. For instance, autistic adults with high IQs have difficulty in differentiating the authenticity of positive facial expressions — genuine and posed smiles; compared to matched controls, autistic adults show an impairment in the discrimination of posed from genuine smiles, and this ability is linked to the degree of deficits in social interaction as measured by the reciprocal social interaction (RSI) of the ADOS (Boraston et al., 2008). They also showed different laughter production patterns: autistic children only produced 'voiced' laughter which is linked to the producers' positive affect, and highly emotionally arousing, whereas their typically developing peers also produced 'unvoiced' laughter, which is less emotionally arousing, and its usage is driven by social interactions and increases with age (Bachorowski et al., 2001; Hudenko et al., 2009; Hudenko & Magenheimer, 2012).

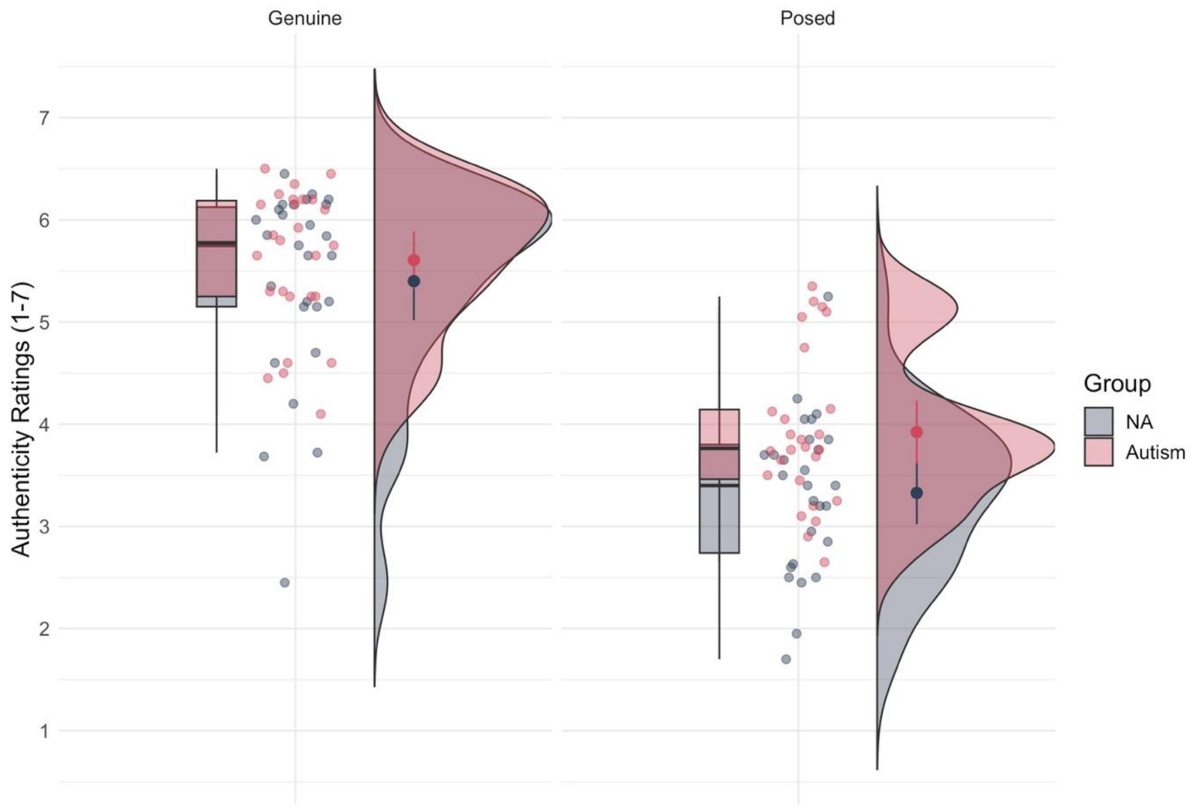
This production preference of autistic people in expressing laughter primarily in response to positive internal states could impact their perceptual pattern of laughter: they are very likely to treat genuine and posed laughter as a similar degree of emotional arousal, reflecting one's internal experience of positive affect.

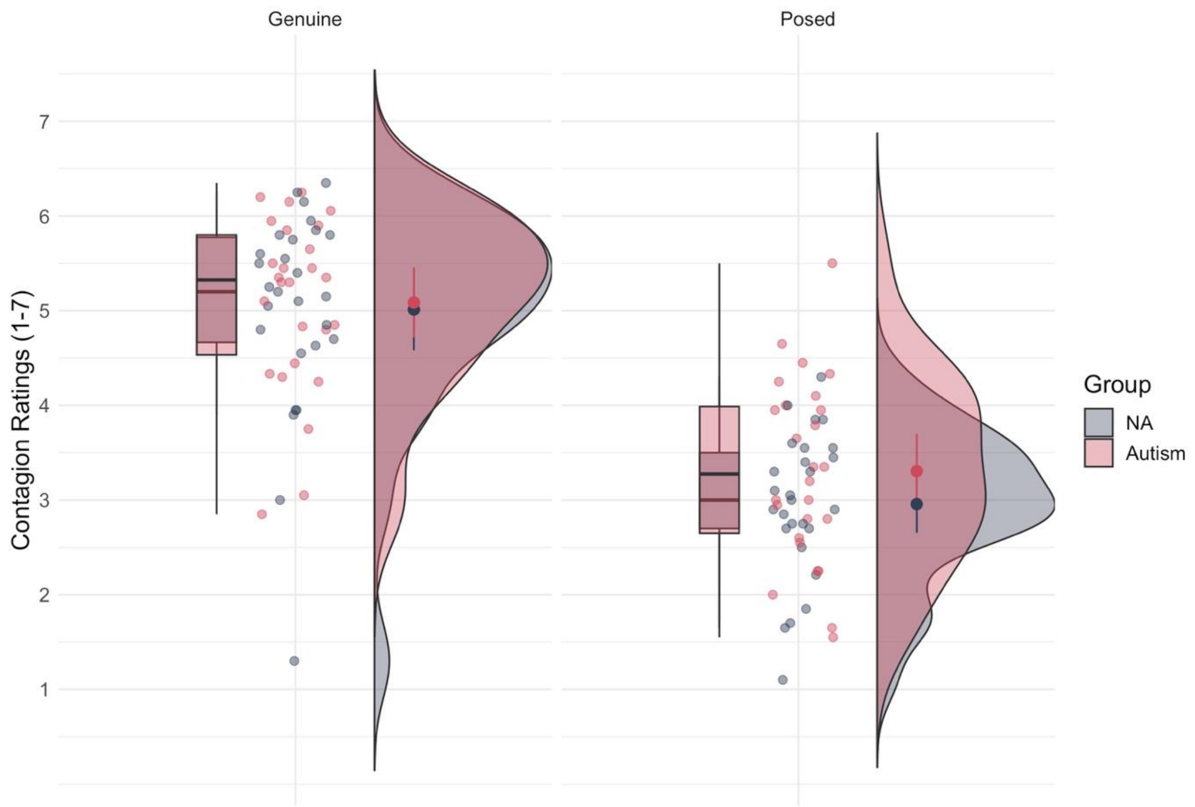
Furthermore, the activation of the prefrontal cortex involved in mentalising network (C. D. Frith & Frith, 2006) has been consistently observed in neurotypical adults during the perception of authentic and positive emotional vocalisation (Warren et al., 2006). Moreover, the activation of amPFC positively correlates with people's ability to differentiate the authenticity of laughter (McGettigan et al., 2015). On this basis, the perceptual difference in posed laughter could be due to poor mentalising performance in autistic people. In summary, the reason why autistic adults show a difference in the perception of posed laughter is currently unclear and requires further research; the difference in laughter perception experienced by autistic adults could be a result of their impairment in the high-level cognitive process (e.g., mentalising ability) which is associated with their unique perception and production pattern in social and communication behaviours (C. D. Frith & Frith, 2006; White et al., 2014).

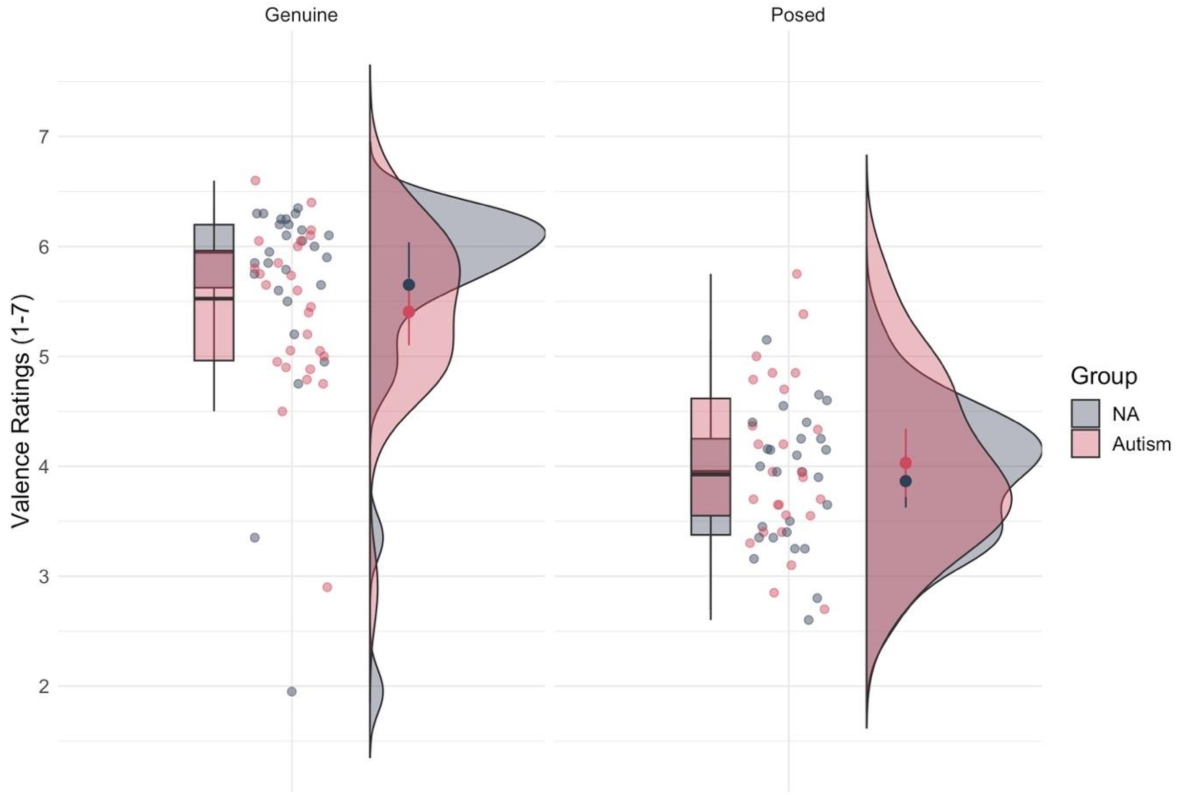
However, we did not find any interaction effect between our groups in either the contagion or valence ratings. It's probably worth noting that both effects were borderline significant, with the autism group results being more similar between the two scales than the non-autism group results. Limitations could primarily explain this in experimental design. In the contagion ratings, we asked participants to give a rating of 'How much does hearing the sound make you feel like joining in and/or feeling the emotion?' on a 7-point scale. The question may not explicitly describe the contagious qualities of laughter. Also, rating scales may lack sensitivity and hence not be ideal for measuring laughter-contagion effects. Therefore, alternative methods for measuring contagion effects should be used in future studies. In the valence ratings, we asked participants to rate each laughter stimulus from ‘highly negative’ to ‘highly positive’, which failed to reflect the nature of laughter as a positive emotional vocalisation. The data from the correlation between authenticity and valence ratings also demonstrated that participants in both groups tend to rate posed laughter as natural stimuli but not a negative emotion. To sum up, whether the perception of contagion or valence of laughter has group differences is currently unclear and requires further research; we would expect to find group differences if such methods are more sensitive and are used in the future.

In summary, the results of this study demonstrated that both autistic and non-autistic adults can discriminate between genuine and posed laughter. However, autistic adults are not as good as non-autistic adults, particularly autistic adults appear to show a perceptual difference in the processing of posed laughter.

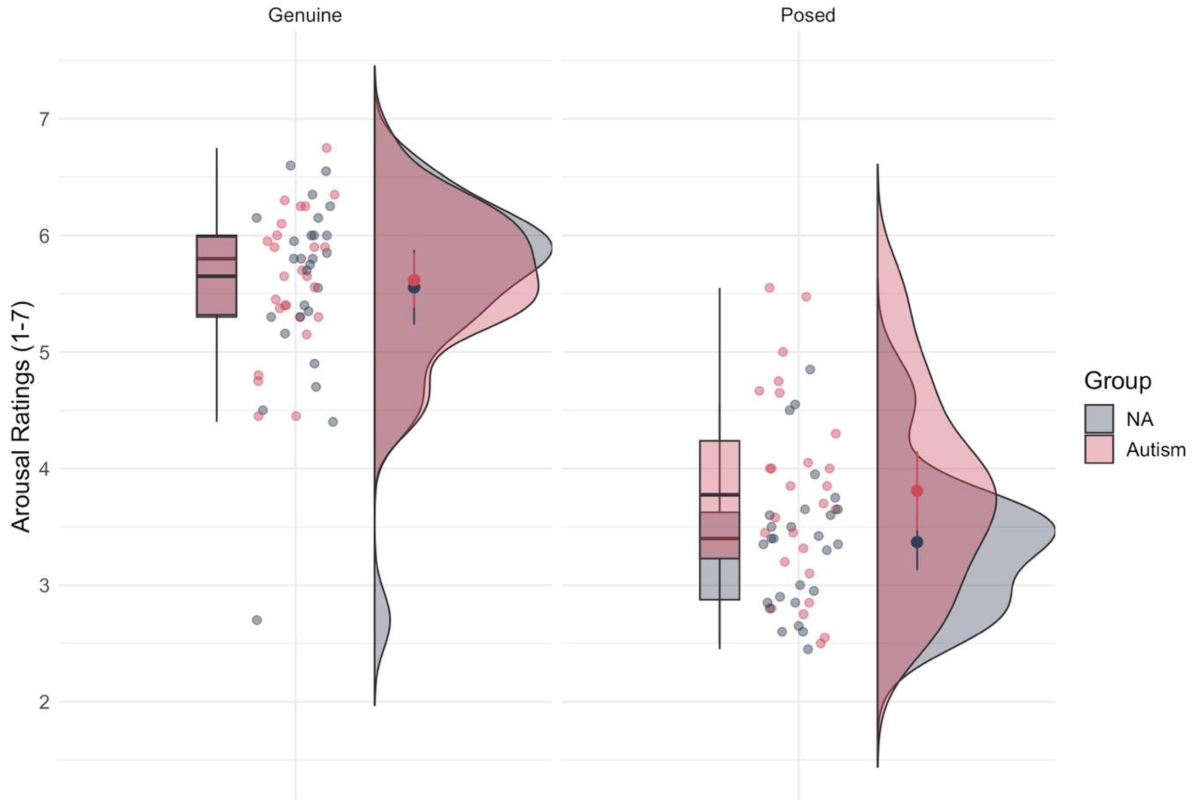
4.6 Appendix 4A







Genuine
Posed
Valence Ratings (1-7)
7
6
5
4
3
2
Group
NA
Autism



Genuine
Posed
Arousal Ratings (1-7)
7
6
5
4
3
2
Group
NA
Autism

Figure 4.6 Rain-cloud plots and box plots of the distribution of ratings across all scales.

Note. Each light dot represents each participant's average rating of one type of laughter on each scale. Each dark dot with line = 1 ± SE.

Chapter 5. Implicit Modulation of Funniness of Humour Stimuli by Laughter

Dataset A in this chapter has been published in Current Biology: Cai, Q., Chen, S., White, S. J., & Scott, S. K. (2019). Modulation of humour ratings of bad jokes by other people’s laughter. *Current Biology*, 29(14), R677-R678.

5.1 Abstract

Previous studies mainly used explicit measures by directly asking participants to make a judgement of perceived affective properties of genuine and posed laughter. In this chapter, we created a novel implicit measure of laughter processing, by adding genuine or posed laughter to a variety of forms of humour stimuli, including puns jokes, burps sounds and slapstick videos, and to see how it affects people's perceived funniness of humour stimuli to be via three datasets. Strikingly, we found the social and emotional meaning of laughter is implicit processing by people. In non-autistic adults, the addition of laughter increased the funniness of humour stimuli perceived to be; and they also found the humour stimuli funnier when paired with genuine than posed laughter. We further investigate whether the same pattern of implicit processing of laughter in non-autistic participants could be found in autistic participants by using an age-, gender- and IQ-matched control group. Surprisingly, this effect was not consistently found in autistic adults. In general, we found autistic adults with high IQs have a different pattern of implicit processing of laughter relative to non-autistic adults.

5.2 Introduction

Throughout laughter research, laughter has long been viewed as an emotional expression in response to humour and amusement, suggesting that people primarily laugh as an involuntary vocalization to reciprocate humour received from others

(Harris & Christenfeld, 1997; Hoicka & Akhtar, 2012; MacDonald et al., 2020; Todt & Vettin, 2005; Weisfeld, 1993; Wild et al., 2003). However, laughter is not always a behaviour in consequence of humour processing, it can be the other way around: the presence of laughter and how laughter is present would influence people perceived funniness and enjoyment of humour circumstances (Gervais & Wilson, 2005; Provine, 1993; Scott et al., 2014; Vettin & Todt, 2004; Weisfeld, 1993). For instance, Bush et al. (1989) found that neurotypical individuals self-reported that the content is funnier and more enjoyable when they hear or see others smiling/laughing in comedy. McKeown and Curran (2016) found that the intensity of laughter is strongly correlated with the degree of perceived humour via a large sample of English and Spanish adults rating audio-visual clips. Within two samples, high-intensity laughter is rated as strongly associated with humour, whilst low-intensity laughter is rated as related to conversational which were only weakly or not at all associated with humour (McKeown & W., 2016).

The aforementioned studies indicate that laughter has a modulating effect on neurotypical adults' perceived funniness to be; they found humour stimuli are subjectively funnier when laughter is present and increasing laughter intensity. Interestingly, a different profile of laughter modulation effect on humour stimuli has been found in autistic groups. Helt & Fein (2016) found typical developing (TD) children rated Tom and Jerry cartoons as more enjoyable when a laugh track is superimposed upon the cartoon than in the absence of any laughter. However, autistic children rated the laughter-track cartoon less enjoyable than their TD peers; and they found the presence of laughter decreased their enjoyment of the cartoon. Besides an opposite tendency of enjoyment ratings in the two groups, Helt and colleagues also found the observed laughter and smiles in the two groups are in line with self-reported enjoyment: TD children laughed more when watching the cartoon with a laughter track than autistic children did (Helt & Fein, 2016a). In Sumiya and colleagues' (2020) study, TD and autistic adults rated their subjective pleasure of jokes stimuli when the jokes were either present without laughter or followed with single or group laughter. In addition, the punchlines of jokes were also manipulated in two ways: either the participant uttered the punchline of the joke, or the participant listened to the punchline read aloud by the computer. The computer punchlines served as baseline funniness measures across all rating conditions in their analysis, and they found greater laughter increment contributed to greater subjective pleasure in both NT and autism groups (Group laughter > Single laughter > No laughter). Although there was no group difference in perceived pleasure in No laughter and Single laughter conditions, a significant difference was found in Group laughter conditions among autism and TD groups. These findings suggest that the laughter increment effect on the perceived pleasure of jokes was lesser in the autism group (Sumiya et al., 2020).

Together the above evidence reveals that the presence of laughter and the way how laughter is present with humour stimuli influence people subjectively perceive that kind of humour stimuli to be, also a perceptual difference of laughter modulation effect has been found in the autistic population. However, these previous designs assumed that laughter is a genuine emotional vocalization elicited by external humour events. In other words, they did not take into account the fact that laughter could either be involuntary or produced under voluntary control when using laughter to manipulate the humour situation. Particularly, we found that autistic adults perceived posed laughter more alike genuine laughter than non-autistic adults (NA) did in Chapter 4.

5.2.1 The Present Study

Therefore, we created a novel implicit measure of laughter processing paradigm to investigate how different types of laughter, genuine, involuntary laughter and posed, voluntary laughter, affect people who perceive the humour stimuli to be by adding laughter to a variety of forms of humour stimuli.

Initially, we investigated the influence of laughter on ratings of the funniness of 'dad jokes' by adding genuine and posed laughter to spoken jokes. Strikingly, we found the same laughter modulation effect was found in autistic and non-autistic groups: the addition of laughter increased the funniness of the jokes were perceived to be, moreover, jokes paired with genuine laughter were perceived as funnier than with the addition of posed laughter. This suggests that the type of laughter is implicitly processed by both autistic and non-autistic adults. However, it is somewhat surprising that no group difference was found in the implicit processing of different types of laughter given the underlying social meaning of laughter (particularly posed laughter acts as a communicative signal) and engagement of mentalizing ability in differentiating two types of laughter (McGettigan et al., 2015; Scott et al., 2014). The failure in detecting any group difference could be due to the baseline funniness of jokes was established in a separate non-autistic group, thus the lack of a well-established baseline measure from the autistic population could not let us make a conclusion on whether there is any difference of implicit laughter processing in autistic and non-autistic adults.

To address this unanswered question, we further conducted a follow-up experiment to collect the baseline ratings of purely the jokes from a matched sample. In the follow-up experiment, we further applied the implicit laughter processing paradigm to non-verbal humour stimuli to replicate our previous findings. Regarding the selection of non-verbal humour stimuli, we used the burp sound as it is non-verbal human vocalization and is commonly used in comedy performances. Additionally, we selected a series of classic slapstick videos to examine whether the laughter modulation effect could be replicated on visual humorous stimuli as well. The design of this follow-up experiment is consistent with the previous design of the joke study, laughter was added at the end of the humour stimuli.

Because slapstick videos often rely on visual punchlines, the timing of when viewers hear the accompanying laughter can significantly impact their perception of the video's funniness. In order to investigate this effect further, we sought to answer two questions: 1) Does the presentation of baseline video stimuli affect people's perception of funniness, and 2) How does the timing of laughter affect the modulation effect on video stimuli? To answer these questions, we manipulated the timing of laughter in the slapstick video stimuli and conducted a follow-up online experiment.

Given the difficulties that autistic people often experience with social communication and mentalizing, as well as the importance of mentalizing in differentiating between genuine and posed laughter, we hypothesized that there would be a difference in the implicit processing of laughter between autistic and non-autistic adults. Specifically, we hypothesized that the addition of laughter would increase the perceived funniness of humour stimuli for non-autistic adults, and that this effect would be influenced by the type of laughter. We predicted that humour stimuli paired with genuine laughter would be perceived as funnier than those paired with posed laughter or presented alone. In contrast, we hypothesized that autistic adults would exhibit a different pattern of implicit processing of laughter on humour stimuli. Specifically, we predicted that the laughter modulation effect would be reduced or absent across all types of humour stimuli for autistic adults.

5.3 Method

5.3.1 Dataset A

Dataset A was collected and published in 2019 (Cai et al., 2019). In total, 26 autistic adults and 48 non-autistic adults were recruited, including a subgroup of 24 NA adults who were matched to the autism group for sex ($\chi2(1) = .242$, $p = .623$), age ($t(48) = -.742$, $p = .462$), and verbal ($t(48) = 1.121$, $p = .268$) and performance ($t(48) = 1.234$, $p = .223$) IQ, as measured by the Wechsler Abbreviated Scale of Intelligence (WASI-II, Wechsler, 1999) or Wechsler Adult Intelligence Scale (WAIS-III/IV; Wechsler, 2008). The groups differed in their self-reported autistic traits, measured by the Autism-Spectrum Quotient (AQ; Baron-Cohen et al. 2001), ($t(47) = -9.068$, $p < .001$). A further separate NA sample was recruited to establish baseline measures of the funniness of the jokes. Full details of the groups are given in Table 5-1.

All participants in the autism group had a diagnosis of autism spectrum disorder (n = 5) or Asperger syndrome (n = 21) from a qualified clinician. The Autism Diagnostic Observation Schedule-2 (ADOS) was administered to verify the diagnosis. In total, nine participants met the criteria for autism and 11 more for autism spectrum on the ADOS classification. The remaining six scored below the threshold but were retained within the sample because five of them scored above the threshold for social symptoms on the ADOS, and they all reported significant difficulties in everyday life; this profile is frequently observed in autistic people with high IQ. Informed written consent was obtained prior to testing, and the project received approval from the UCL research ethics committee.

Table 5-1 Background details of the participant groups in Dataset A

	Autism	NA Subgroup	NA	Baseline group
N (male: female)	26 (21:5)	24 (18:6)	48 (28:20)	20 (8:12)
Age (years)	34.885 (7.706)	33.000 (5.693)	26.000 (7.380)	27.800(4.011)
Verbal IQ	115.846 (10.130)	118.233 (12.724)		
Full-Scale IQ	114.692 (11.589)	116.533 (14.827)		
AQ[a]	33.160 (8.740)	16.067 (7.719)		
ADOS total	8.654 (3.382)	-	-	-
-communication subscale	3.308 (2.346)	-	-	-
-social subscale	5.731 (2.393)	-	-	-

Note. Values are given as mean (standard deviation), except when otherwise stated.

NA = non-autistic; AQ = autism-spectrum quotient.

[a] One autistic participants did not complete the AQ.

5.3.2 Dataset B

In a follow-up experiment, 28 autistic adults and 67 non-autistic adults were recruited from the Autism@ICN and UCL SONA participant databases one year later.

The 28 autistic participants had previously received a diagnosis of Autism Spectrum Disorder (n = 12) or Asperger syndrome (n = 16) from a qualified clinician. The Autism Diagnostic Observation Schedule (ADOS-2, module 4; Hus & Lord, 2014) was used to verify the diagnoses of 26 autistic participants. Eighteen of the autistic participants either met the criteria for autism (n = 13) or autism spectrum classification (n = 5). The remaining eight scored below the threshold but were retained within the sample because five had an AQ score above the 32 cut-off point and all reported significant social difficulties in everyday life. Furthermore, ADOS has been shown to be less sensitive in diagnosing autistic people with IQ in the normal or above-average range (Kamp-Becker et al., 2013).

Non-autistic participants were over-recruited to match a NA subgroup as closely as possible to the autistic group: we excluded females aged below 31 (n = 26) and males aged below 25 (n = 11). Thus, 30 NAs have remained in the NA subgroup for group comparisons. These groups were comparable on sex ($\chi^2(1) = .646$, $p = .421$), age ($t(56) = .722$, $p = .473$), and verbal ($t(56) = -.803$, $p = .426$) and full-scale ($t(56) = -.631$, $p = .531$) IQ (Wechsler Adult Intelligence Scale (WAIS-III/IV), Wechsler, 2008). As expected, the autism group self-report more autistic traits (Autism-Spectrum Quotient (AQ); Baron-Cohen et al., 2001; $t(56) = 6.876$, $p < .001$). Full details of the two groups are given in Table 5-2.

Table 5-2 Background details of the participant groups in Dataset B

	Autism	**NA Subgroup**	**NA**
N (male: female)	28 (23:5)	30 (22:8)	67 (33:34)
Age (years)	34.143 (6.364)	33.000 (5.693)	27.642 (6.552)
Verbal IQ	115.214 (15.847)	118.233 (12.724)	120.119 (14.523)
Full Scale IQ	113.929 (16.615)	116.533 (14.827)	117.881(15.326)
AQ	32.357 (10.228)	16.067 (7.719)	14.955 (7.951)
ADOS total [a]	8.962 (4.142)	-	-
-communication subscale	2.692 (1.715)	-	-
-social subscale	6.269 (3.027)	-	-

Note. Values are given as mean (standard deviation), except when otherwise stated. NA = non-autistic; AQ = autism-spectrum quotient. [a] Two autistic participants did not complete the ADOS.

In particular, 20 participants (Autism, n = 12; NA subgroup, n = 8) in Dataset B participated in the previous study collected in Dataset A. The autistic group and NA subgroup in Dataset B were comparable with the autistic group and NA subgroup in Dataset A. See Table 5-3.

Table 5-3 Participants comparison between groups in Dataset A and B

	NA subgroup in A	NA subgroup in B	Between groups comparison
N (male: female)	24(18:6)	30 (22:8)	$\chi^2(1) = .019$, $p = .890$
N (%) of 2019 participated in the 2018	N/A	8 (14.8%)	N/A
Age (years)	32.917 (5.693)	33.000 (5.693)	$t(32.889) = .034$, $p = .973$
Verbal IQ	119.042 (10.002)	118.233 (12.724)	$t(52) = -.254$, $p = .800$
Full Scale IQ	118.792 (11.409)	116.533 (14.827)	$t(52) = -.614$, $p = .542$
AQ	13.708 (5.953)	16.067 (7.719)	$t(52) = 1.231$, $p = .224$
	Autism in A	**Autism in B**	**Between groups comparison**
N (male: female)	26(21:5)	28 (23:5)	$\chi^2(1) = .017$, $p = .897$
N (%) of 2019 participated in 2018	N/A	12 (22.2%)	N/A
Age (years)	34.885 (7.706)	34.143 (6.364)	$t(52) = -.387$, $p = .700$
Verbal IQ	115.846 (10.130)	115.214 (15.847)	$t(46.306) = -.176$, $p = .861$
Full Scale IQ	114.692 (11.589)	113.929 (16.615)	$t(52) = -.194$, $p = .847$
AQ [a]	33.160 (8.740)	32.357 (10.228)	$t(51) = -.305$, $p = .761$
ADOS total [b]	8.654 (3.382)	8.962 (4.142)	$t(50) = .293$, $p = .770$
- communication subscale	3.308 (2.346)	2.692 (1.715)	$t(50) = -1.080$, $p = .285$
- social subscale	5.731 (2.393)	6.269 (3.027)	$t(50) = .712$, $p = .480$

Note. Values are given as mean (standard deviation), except when otherwise stated. NA = non-autistic; AQ = autism-spectrum quotient. All the p-value were reported in two-tailed. [a] one autistic participant did not complete the AQ questionnaire. [b] two autistic participants did not complete the ADOS.

5.3.3 Dataset C

In the follow-up implicit laughter processing on the slapstick video task, two further online samples were recruited via Prolific (www.prolific.co).

The first samples included 52 NA adults (37 females: average age = 24.072, *SD* = 4.423) and 39 autistic adults. NA participants aged below 28 and with a score on the verbal task below 60 (n = 21) were excluded from the NA sample to provide a good match. Two participants were excluded from the autistic group as they self-identified as autistic but had no clinical diagnosis, and both scored below the cut-off of

7 on the AQ-10. The resulting groups were comparable on sex ($\chi^2(1) = .813$, $p = .367$), age ($t(66) = -.724$, p = .472), verbal ($t(66) = -.987$, $p = .327$), and non-verbal ($t(66) = .240$, $p = .811$) ability (Spot-the-Word test (StWt), Baddeley et al., 1993 and Matrix Reasoning Item Bank (MaRs-IB), Chierchia et al., 2019). As expected, the groups differed in their self-report of autistic traits, measured by the Autism-Spectrum Quotient 10-item (AQ-10; Baron-Cohen et al., $t(64) = 8.801$, $p < .001$).

The second set included 42 NA adults (26 females: average age = 24.381, *SD* = 4.737). Full details of the two groups are given in Table 5-4.

Table 5-4 Background details of the participant groups in Dataset C

	Dataset C ver 1			Dataset C ver 2
	Autism	**NA Subgroup**	**NA**	**NA**
N (male: female)	37 (12:25)	31(7:24)	52 (15:37)	42 (16:26)
Age (years)	26.989 (6.122)	26.050 (4.546)	24.072 (4.423)	24.381 (4.373)
Verbal ability	76.838 (11.784)	74.226 (9.653)	-	-
Non-verbal ability	61.432 (20.781)	62.581 (18.222)	-	-
AQ-10 [a]	7.286 (2.346)	3.032 (1.538)	-	-

Note. Values are given as mean (standard deviation). NA = non-autistic; AQ = autism-spectrum quotient. [a] Two autistic participants did not complete the AQ-10.

5.3.4 Experimental design and procedure

5.3.4.1 Dataset A

In this dataset, all the participants were engaged in one task: Implicit modulation of the funniness of jokes by laughter.

5.3.4.1.1 Implicit modulation of funniness of jokes by laughter

Laughter stimuli. The laughter stimuli (40 in total), consisting of 20 genuine (involuntary) and 20 posed (voluntary) laughter stimuli, were selected from the emotional vocalisation dataset (100 in total) recorded from a previous study (see Chen, 2018). See Chapter 3 for more details.

Jokes stimuli. Forty jokes involving puns and wordplay were read aloud by a professional male comedian in a performance style and recorded as stimuli. Full details of the jokes are given in the Appendix: we avoided jokes that rely on the interpretation of intentions or social rules. The jokes were all somewhat puerile: this was to avoid a ceiling effect that might mask any effects of added laughter. Recordings were made on a digital audio recorder. The raw audio files were downsampled at a rate of 44100 Hz to mono.wav files with 16-bit resolution. The duration of each joke stimulus was edited and cut into complete sound clips from 3 to 6 seconds.

Experimental Design. We further edited the jokes stimuli by randomly pairing each joke stimulus with either a genuine or a posed laughter stimulus. Each combined stimulus (joke paired with either genuine or posed laughter stimulus) was further edited into a separate .wav file (< 9s each) using version 2.3.0 of Audacity(R) recording and editing software. This process resulted in 80 combined stimuli and was assigned to two sets: each set contained 40 stimuli with half of the jokes (J) paired with genuine laughter (Genuine) and half paired with posed laughter (Posed); the second set contained the same 40 jokes but paired with the alternative form of laughter. Participants listened to the 40 combined stimuli from either Set 1 or Set 2. All combined stimuli were counterbalanced between two stimuli sets and randomly presented across participants, such that we could determine the effects of laughter type on the perception of humour in the joke (see Figure 5.1).

At the beginning of the task, participants were instructed that we had recorded some jokes read by a male comedian and different people's responses to the jokes. To help this amateur comedian to get some feedback on his performance, the participants would wear headphones (Sennheiser headphones HD 221) and listen to those recordings and make a judgment of how funny each recording was on a 7-point rating slider ('How funny is the joke?' 1 – Not funny at all, 7 - Extremely funny). For each testing trial, they had up to 6 seconds to give a response on a slider that could be moved with the mouse. There were also eight catch trials in the task to ensure that participants paid attention to the stimuli, presented after every fifth testing trial. The catch trials required the participants to recall whether the laughter in the preceding joke stimulus was produced by a female or male speaker.

5.3.4.1.2 Experimental procedure

Informed written consent was obtained prior to testing, and the project received approval from the UCL research ethics committee. Testing was administered by one experimenter in a testing room. All participants were asked to sit directly in front of the laptop and wear headphones. Before the test session started, each participant confirmed that he or she understood the task and had had the opportunity to ask any questions. The first trial began after participants clicked the start button. The whole task took around 10 minutes and was presented in Gorilla Experiment Builder (https://gorilla.sc/). At the conclusion of the testing, the experimenter asked whether participants had any further questions and gave them payment for taking part in the study (£10 per hour). Participants were also encouraged to contact the researchers if they had any further questions.

5.4.4.2 Dataset B

In this dataset, all the participants competed for three tasks: i) Baseline ratings of jokes; ii) Implicit modulation of funniness of burps by laughter, and iii) Implicit modulation of funniness of slapstick videos by laughter.

5.4.4.2.1 Baseline Ratings of Jokes Stimuli

The same 40 joke stimuli involving puns and wordplay were used in the current baseline rating task. The task consists of 40 trials of rating the funniness of original jokes stimuli (with the absence of laughter). The same instruction and rating 7-point rating slide were used in this task. In addition, three 'Yes/No' questions were followed by the rating to measure the Meaning ('Do you understand why it's meant to be funny?') and Familiarity ('Have you seen this video clip before?'), and whether Mentalizing ('Do you need to consider other people's thoughts and feelings in order to understand this video clip?') was involved in understanding each joke stimulus.

5.4.4.2.2 Implicit modulation of funniness of burps by laughter

Twenty-one burp sound files were selected from YouTube (CRAKOS22. Retrieved from: https://www.youtube.com/@CRAKOS22) and were trimmed into complete sound clips in Audacity(R) (version 2.3.3; https://www.audacityteam.org). The raw audio files underwent noise reduction, were stereo-track synced, amplified to a -12dB playback and down-sampled at a rate of 44100 Hz to stereo.wav files with a 32-bit resolution (average duration = 1.260 seconds; *SD* = 0.233; range = .914).

We further edited the burp stimuli by randomly pairing each burp stimulus with either a genuine or a posed laughter stimulus. Therefore, fourteen laughter stimuli (seven genuine and seven posed) were randomly selected from the original laughter stimuli set. This process resulted in 42 combined stimuli (21 burps + genuine laugh and 21 burps + posed laugh), and the gap between the burp and laugh was around 100ms. The combined stimuli were edited into a separate stereo.wav file, amplified to a -12dB playback, down-sampled at a rate of 44100Hz to stereo.wav files with a 32-bit resolution in Audacity(R), and normalised for RMS amplitude by using Praat (Boersma & Weenink, 2014).

The design of the current task was adapted from the previous jokes study. Forty-two combined stimuli and 21 burps stimuli without laughter were assigned to three stimuli-sets: each stimuli-set contained 21 sound stimuli, including seven burps stimuli (Burps Baseline), seven burps paired with genuine laughter (Burps+Genuine), and seven burps paired with posed laughter (Burps+Posed). (see Figure 5.1).

The acoustic features of the sound stimuli in three stimuli-sets were comparable for the total duration ($F[2,60] = .024$, $p = .977$), root-mean-square ($F[2,60] = .036$, $p = .965$), mean intensity ($F[2,60] = .036$, $p = .965$), pitch mean ($F[2,58] = .391$, $p = .678$), pitch standard ($F[2,58] = .446$, $p = .642$), median pitch ($F[2,58] = .274$, $p = .761$), spectrum centre of gravity ($F[2,60] = .309$, $p = .735$), fraction of locally unvoiced frames ($F[2,60] = .003$, $p = .997$), jitter (local) ($F[2,60] = .774$, $p = .466$), shimmer (local, dB) ($F[2,58] = .283$, $p = .755$) and mean harmonics-to-noise ratio ($F[2,58] = .478$, $p = .623$) as extracted using Praat (Boersma & Weenink, 2014).

Participants were instructed that they would hear some sounds and give a rating for its funniness level for each stimulus on a 7-point rating slider ('How funny is the sound?' 1 – Not funny at all, 7 - Extremely funny). They listened to 21 sound stimuli from one of the three stimuli sets: within each set, seven trials of burps baseline stimuli were always presented first, followed by the remaining 14 trials of burps with laughter stimuli were randomly presented to avoid any order effect. To ascertain the effect of laughter and the type of laughter on burp perceived funniness, all combinations of types of burps stimuli (Burps Baseline, Burps+Genuine, Burps+Posed) were counterbalanced between three stimuli-sets across participants.

5.4.4.2.3 Implicit modulation of funniness of slapstick videos by laughter

Slapstick comedy films included Charlie Chaplin, Buster Keaton, Laurel & Hardy and Harold Llody were selected from YouTube. The soundtracks were deleted, and the films were trimmed into 30 video clips (average duration = 7.546 seconds; SD = 2.861; range = 10.280) exported as 720 high-quality HD mp4 format by using Adobe Premiere (R) (version 2.3.3; https://www.audacityteam.org).

To be consistent with the previous task design, each video clip was randomly edited with either a genuine or a posed laughter stimulus, and the laughter stimulus was added on purpose at the end of each video clip when its first frame was tuned into black. Therefore, 20 laughter stimuli (10 genuine and 10 posed) were randomly selected from the rest of the laughter stimuli pool and were edited with the 30 video clips. The gap between the last frame of the video clips and the onset of laughter was around 50 to 100ms. This process resulted in 60 combined stimuli (30 videos + genuine laugh and 30 videos + posed laughter) and was exported as 720 high-quality HD mp4 format with AAC stereo audio tracks by using Adobe Premiere (R) (version 2.3.3; https://www.audacityteam.org).

Sixty combined stimuli and 30 video stimuli without laughter were assigned to three stimuli-sets: each stimuli-set contained 30 stimuli, including ten videos stimuli (Videos Baseline), ten videos paired with genuine laughter (Videos+Genuine), and ten videos paired with posed laughter (Videos+Posed) (see Figure 5.1).

Participants were instructed that they would watch some funny video clips. For each stimulus, they will be asked to give a rating for its funniness level on the same 7-point rating slider ('How funny is this video clip?' 1 – Not funny at all, 7 - Extremely funny). They watched 30 video stimuli from one of the three stimuli-sets: within each set, ten trials of videos baseline stimuli were always presented first, followed by the remaining 20 trials of videos with laughter stimuli which were randomly presented to avoid any order effect. To ascertain the effect of laughter and the type of laughter on videos' perceived funniness, all combinations of types of video stimuli (Videos Baseline, Videos+Genuine, Videos+Posed) were counterbalanced between three stimuli-sets across participants.

5.4.4.2.4 Experimental procedure

Informed written consent was obtained from all participants prior to testing, and the project received approval from UCL's research ethics committee. Testing was administered by one experimenter in a testing room. All participants were asked to sit directly in front of the laptop, and it was explained that they were going to complete a questionnaire and several tasks.

At the beginning of the study, participants were told to fill in a short online questionnaire. The 10-item Positive Affect Schedule (PAS-10; Watson, Clark, & Tellegen, 1988) was used as a baseline emotion measure by asking the participants 'indicate to what extent you feel this way right now, that is, at the present moment'. No significant difference has been found in the baseline emotion between the NA subgroup (M = 32.000, SD = 6.534) and the autism group (M = 29.821, SD = 7.273), $t(56)$ = 1.202, p = .253.

Before starting the following tasks, participants were instructed that they would listen to some sounds and watch some video clips. For each stimulus, they would be asked to give a rating for its funniness level and to give an answer to some "yes/no" questions. The experiment was split into 3 sessions; session one was the baseline ratings of the jokes task, session two was the burps task, and session three was the videos task. There was a short break between each task. Participants were also informed to wear headphones during the whole experiment.

In all three sessions, all the stimuli will only be present one time, and there was a practice trial before the real task, during which participants had the opportunity to practice with the slider and to ask questions if they did not understand the task. The participants were asked to pay attention to each recording/video clip and to respond as quickly as possible. The first testing trial began after the participant clicked the start button. After the participant had rated the funniness of the stimulus, the next trial immediately began. Participants couldn't skip trials; to move on they had to give a response. See Figure 5.1 for the testing procedure and experiment paradigm.

After testing, the experimenter asked whether participants had any further questions and gave them payment (£10 per hour). Participants were also encouraged to contact the researchers if they had any further questions. The experiment took around 30 minutes and was presented in Gorilla Experiment Builder (https://gorilla.sc/).

5.4.4.3 Dataset C

In this dataset, participants competed for the online version of implicit modulation of the funniness of slapstick videos by laughter task.

5.4.4.3.1 The updated version of Implicit modulation of funniness of slapstick videos by laughter

The 30 slapstick video clips and the 20 laughter stimuli (10 genuine and 10 posed; average duration = 2.531 sec, SD = .266) are identical to the stimuli used in the previous video task.

In the updated version of video tasks, laughter was added at the exact punchline of each video clip instead of presented in the last frame of the slapstick video clips. The punchline of each video was annotated and agreed upon by three markers: two researchers (C.Q.C. and S.K.S) and one TV sound editor with experience in editing sound for comedy programmes (J.M.).

In online version one, non-emotional and natural human vocalisations, a sound recording of eating apple or crisps sound clips (five sound clips for each category; average duration = 2.530 sec, SD = .215) were used as baseline sound stimuli. Ten baseline sound clips and 20 laughter stimuli were normalised for RMS amplitude in Praat (Boersma & Weenink, 2014). All 30 video clips were further edited by adding either a baseline or a genuine/posed laughter stimulus at the annotated punchline and exported as 720 high-quality HD mp4 format with AAC stereo audio tracks in Adobe

Premiere (R) (version 2.3.3; https://www.audacityteam.org). This process resulted in 90 video stimuli assigned to three stimuli-sets; each stimuli-set consisted of 30 stimuli, including 10 baseline videos (video + eating apple/crisps sound), 10 videos + genuine laughter, and 10 videos + posed laughter.

In online version two, 30 video clips were further edited by adding either a genuine or a posed laughter stimulus at the annotated punchline and exported as 720 high-quality HD mp4 format with AAC stereo audio tracks in Adobe Premiere (R) (version 2.3.3; https://www.audacityteam.org). However, the baseline video clips remained silent (deleted soundtrack) as in the previous 2019 in-lab design. This process resulted in 90 video stimuli assigned to three stimuli sets; each stimuli-set consisted of 30 stimuli, including 10 baseline videos (silent videos), 10 videos + genuine laughter, and 10 videos + posed laughter (see Figure 5.1).

Participants were instructed that they would watch some funny video clips. For each stimulus, they will be asked to give a rating for its funniness level on the same 7-point rating slider ('How funny is this video clip?' 1 – Not funny at all, 7 - Extremely funny). They watched 30 video stimuli from one of the three stimuli sets. However, 30 trials of video clips were fully randomised in all three sets to avoid any potential order effect.

5.4.4.3.2 Experimental procedure

Two versions of online video tasks were recruited separately via Prolific (www.prolific.co). Informed written consent was obtained online from all participants prior to testing, and the project received approval from UCL's research ethics committee. The instruction and display of the two versions of tasks remained the same as the previous in-lab video task presented in Gorilla Experiment Builder (https://gorilla.sc/). The task took around 15min, and the participants were paid £7.5 per hour.

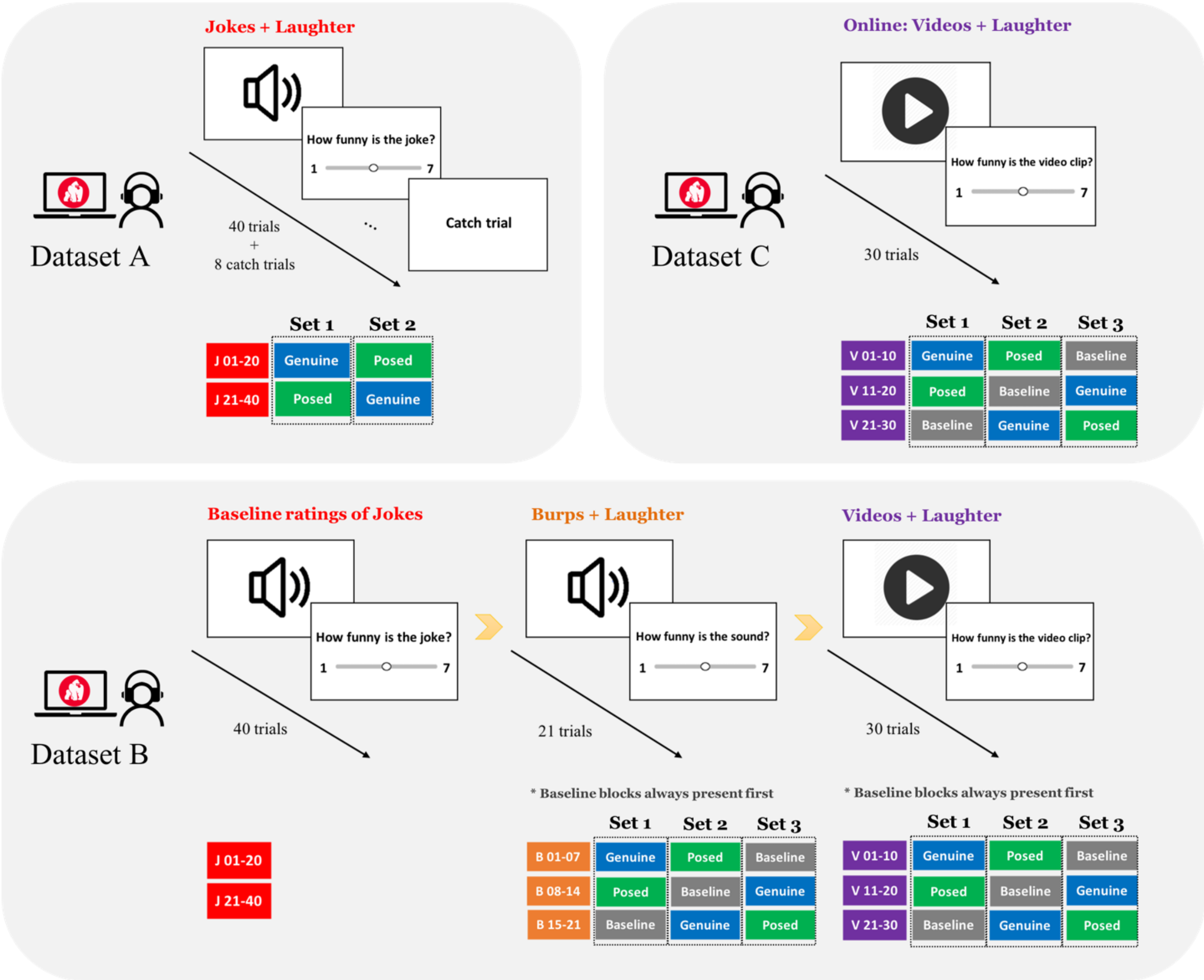


Figure 5.1 Experimental design and testing procedure in Dataset A (upper left), Dataset B (bottom), and Dataset C (upper right)

5.5 Results

In the current section, the results will be presented by the stimuli types, but not in the order of the datasets. Instead, I will report participants' performance based on the tasks, namely, i) Implicit modulation of funniness of jokes by laughter, ii) Implicit modulation of funniness of burps by laughter, and iii) Implicit modulation of funniness of slapstick videos by laughter. Specifically, I will first illustrate the profile of laughter modulation effect on non-autistic participants among the three tasks, and then report the findings from the matched groups, the non-autistic subgroup and autistic group, to demonstrate the different pattern0 of implicit laughter processing between the two groups.

An item-based analysis was conducted on all the tasks; each humour stimulus (e.g., joke, burp sound, video clip) was treated as an item in the statistical analysis. This analysis was chosen as items were designed to produce a range of different funniness ratings. In this way, the effect of adding laughter to the funniness of each humour stimulus could be assessed. Data were analysed in IBM SPSS Statistics (version 26; www.ibm.com/uk-en/products/spss-statistics) and RStudio Team (2020). P values were reported as two-tailed unless specified.

5.5.1 Laughter modulation effect on non-autistic group

5.5.1.1 Implicit modulation of funniness of jokes by laughter

Two versions of baseline ratings of the joke stimuli have been collected from separate NA participants in dataset A and dataset B. Therefore, analysis has been conducted independently on each dataset.

In dataset A, the baseline ratings of jokes were collected from the separate NA group (BL; n = 20), combined with the ratings of jokes with laughter (NA; n = 48). A one-way repeated measure analysis of variance (ANOVA) was conducted as the Type of jokes (baseline vs genuine vs posed laughter) was the within-subject factor. There was a significant main effect of Type, $F[2,78] = 28.549$, $p < .001$, $\eta_p^2 = .423$, indicating that the NA rated the funniness of jokes significantly differed between different types of joke stimuli. Post hoc analysis with a Bonferroni adjustment revealed that the perceived funniness of jokes stimuli was statistically significantly increased from baseline ratings of jokes (*M* = 2.708, *SD* = .505) to jokes with posed laughter (*M* =

3.002, *SD* = .488, *p* < .001) and from jokes with posed laughter to jokes with genuine laughter (*M* = 3.232, *SD* = .484, *p* = .004 < .01).

To establish a precise profile of the jokes baseline, we further collected the baseline rating of the jokes from a larger sample of NA participants (NA; n = 67) in dataset B. Additionally, the baseline ratings of jokes were further excluded based on the answer of Meaning ('Do you understand why it's meant to be funny?') trial by trial, such that an average baseline rating for each joke item is calculated across all the participants only if participants have reported a 'Yes' on the following Meaning measure. Combined with the pre-collected ratings of jokes with laughter (NA; n = 48) in Dataset A. A one-way repeated measure analysis of variance (ANOVA) was conducted as the Type of jokes (baseline vs genuine vs posed laughter) was the within-subject factor in evaluating the laughter modulation effect on the perceived funniness of jokes among the NA population. There was a significant main effect of Type, $F[2,78] = 89.979$, $p < .001$, $\eta_p^2 = .698$, indicating that the NA rated the funniness of jokes significantly differed between different types of joke stimuli. Post hoc analysis with a Bonferroni adjustment revealed that the perceived funniness of jokes stimuli was statistically significantly increased from baseline ratings of jokes (*M* = 2.471, *SD* = .392) to jokes with posed laughter (*M* = 3.002, *SD* = .488, *p* < .001) and from jokes with posed laughter to jokes with genuine laughter (*M* = 3.232, *SD* = .484, *p* = .004 < .01) (See Figure 5.2).

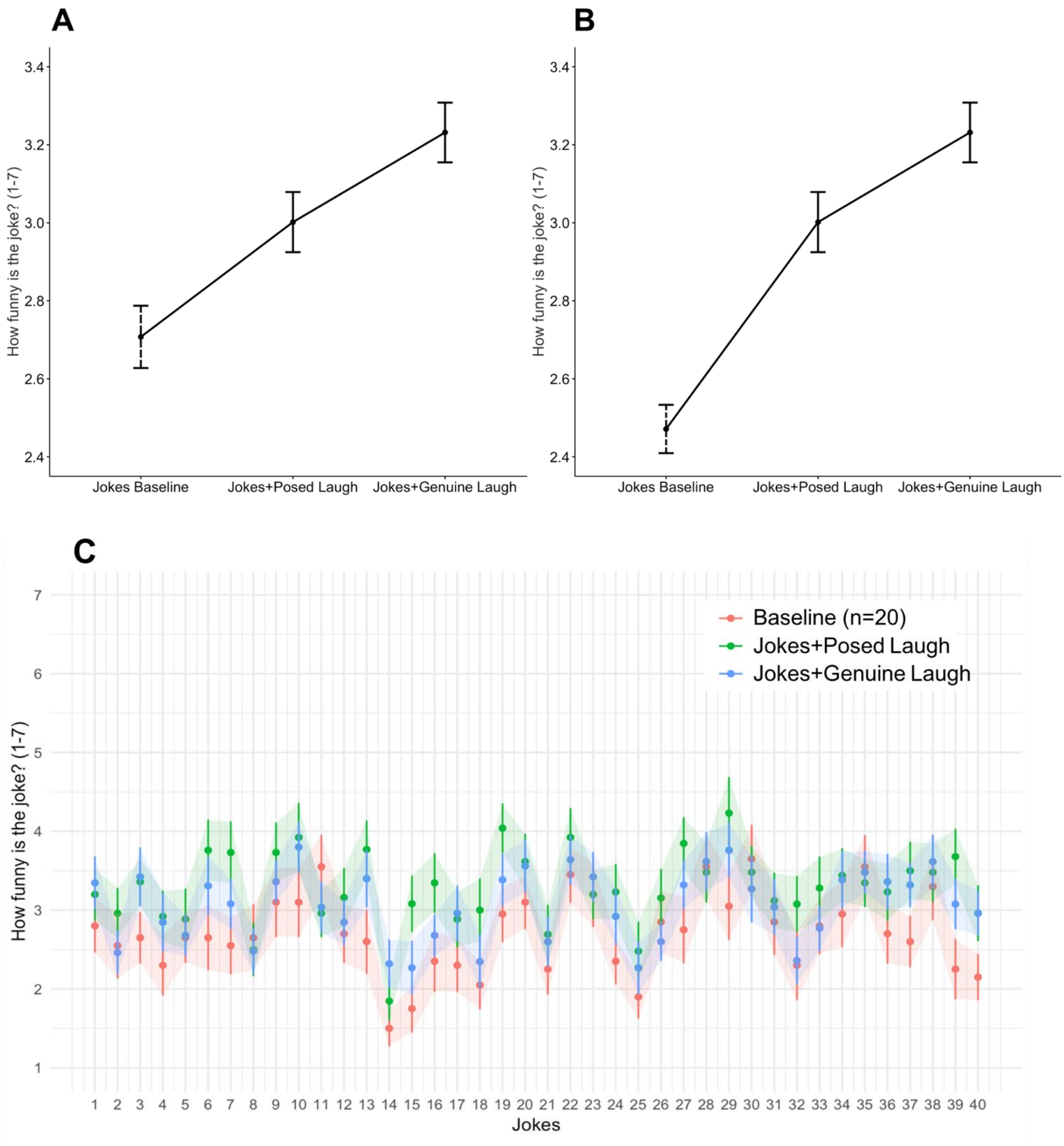


Figure 5.2 Effect of laughter on humour ratings of jokes on the non-autistic participant

Note. Graph A: Effect of genuine and posed laughter on humour ratings of jokes on non-autistic participants in Dataset A; Baseline (dashed line) collected from a separate non-autistic group (n = 20). Graph B: Effect of genuine and posed laughter on humour ratings of jokes on non-autistic participants in Dataset B; Baseline (dashed line) collected from a separate non-autistic group (n = 67). Graph C: Average ratings for 40 jokes and 40 jokes paired either genuine or posed laughter in NT participants (n = 48) in Dataset A; Baseline (in red) collected from a separate non-autistic group (n = 20). Error bars: ± 1 SE in A, B, C.

5.5.1.2 Implicit modulation of funniness of burps by laughter

One-way repeated measure analysis of variance (ANOVA) was conducted with the Type of burps (baseline vs genuine vs posed laughter) as the within-subject factor. There was a significant main effect of Type, $F[2,40] = 23.380$, $p < .001$, $\eta_p^2 = .539$, indicating that the NA rated the funniness of burps significantly differed between different types of burp stimuli. Post hoc analysis with a Bonferroni adjustment revealed that the perceived funniness of burp stimuli was statistically significantly increased from the burps presented alone ($M = 2.000$, $SD = .303$) to burps with posed laughter ($M = 2.408$, $SD = .264$, $p = .003 < .01$) and from burps with posed laughter to burps with genuine laughter ($M = 2.723$, $SD = .382$, $p = .039 < .05$) (See Figure 5.3).

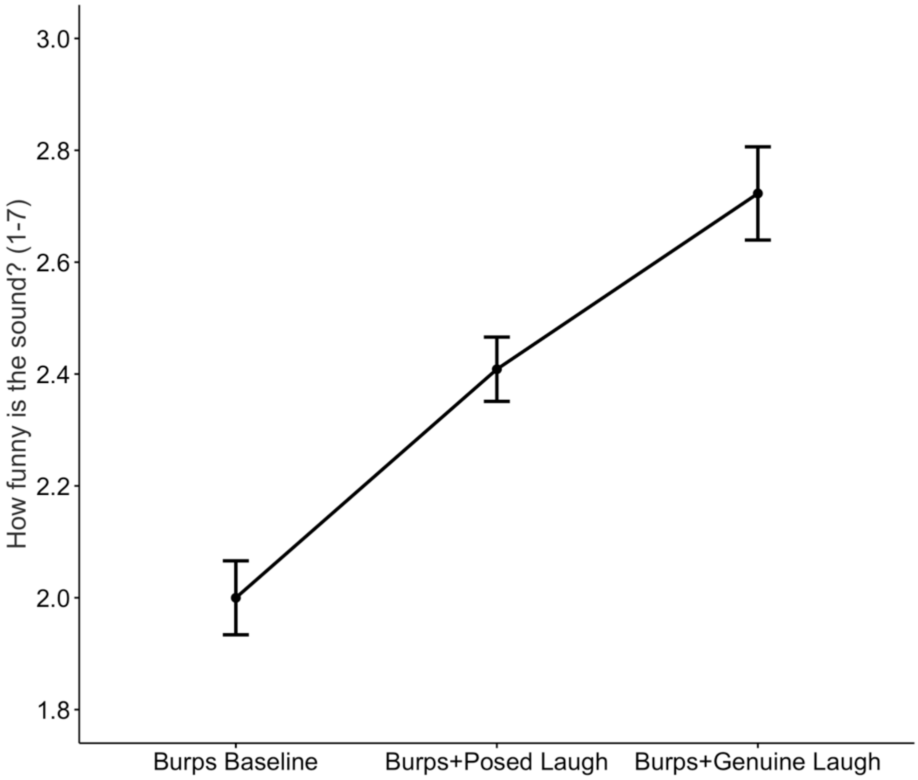


Figure 5.3 Effect of genuine and posed laughter on humour ratings of burps on the non-autistic participant

Note. Error bars: ± 1 SE.

5.5.1.3 Implicit modulation of funniness of slapstick videos by laughter

Three consecutive versions of implicit modulation of the funniness of slapstick videos by laughter have been conducted to answer the question of whether the same laughter modulation effect could be found in visual humorous stimuli.

Firstly, a 3 x 3 repeated measures analysis of variance (ANOVA) was conducted, including the Version of video tasks (Dataset B vs Dataset C Ver1 vs Dataset C Ver2) and Type of video stimuli (baseline vs genuine laughter vs posed laughter) as the within-subject factors. For the main effect of Version and Type, sphericity was met, as indicated by Mauchly's test. However, for the Version by Type interaction, Mauchly's test indicated a violation of the sphericity assumption, $\chi^2(9)$ =

23.668, p = .005. Since sphericity is violated (ε = 0.663), Greenhouse-Geisser corrected results are reported. The results show that there was no significant main effect on Version, $F[2,58] = 2.059$, $p = .137$, $\eta_p^2 = .066$, and on Type, $F[2,58] = 1.347$, $p = .268$, $\eta_p^2 = .044$, suggesting neither different Versions nor different Types were rated significantly funnier than the others. However, a significant interaction effect between Version and Type was found, $F[2.654,79.960] = 5.237$, $p = .004 < .01$, $\eta_p^2 = .153$, indicating that the effect on perceived funniness of presenting different types of video stimuli was different across three versions of video tasks. Post hoc analysis with a Bonferroni adjustment revealed that the perceived funniness of slapstick videos only showed a significant difference in the baseline ratings across three versions of tasks, $F[2,58] = 12.428$, $p < .001$, $\eta_p^2 = .300$. The baseline videos (silent videos in Dataset B) were rated significantly funnier when they presented as the first block (M = 3.609, SD = .628) than when the baseline trials and video-with-laughter trials were shuffled (two online versions in Dataset C). No matter when compared with the baseline videos paired with non-emotional and natural human vocalisations (M = 3.170, SD = .602, $p < .001$) or when the baseline videos were also silent but randomised presented with other trials (M = 3.211, SD = .662, $p < .001$). Moreover, participants rated the randomised baseline videos were the same level of funniness when either paired with non-emotional human vocalisations or silent. However, no such effect has been detected on the ratings of videos with laughter (posed and genuine) across three versions of tasks.

The results of baseline ratings of slapstick videos illustrated the nature of visual stimuli and acoustic stimuli is distinct, and the way in which they were presented can have a strong impact on how people perceive their funniness. Presenting the silent video as the first block (Dataset B) could not reveal a true story of the laughter modulation effect on slapstick videos. Therefore, we excluded the data from Dataset

B and collapsed the data from two online versions in Dataset C to further explore the laughter modulation effect on visual humorous stimuli among the NA population. A one-way repeated measure analysis of variance (ANOVA) was conducted with the Type of videos (baseline vs genuine vs posed laughter) as the within-subject factor. There was a significant main effect of Type, *F*[2,58] = 2.865, *p* = .0325 < 0.05 one-tailed, η_p^2 = .090, indicating different types of video stimuli have a significant difference in NA perceived the funniness to be. Post hoc analysis with a Bonferroni adjustment revealed that the perceived funniness of videos showed an increased tendency from the baseline videos (*M* = 3.192, *SD* = .571) to videos with posed laughter (*M* = 3.288, *SD* = .587) and to videos with genuine laughter (*M* = 3.365, *SD* = .506). In addition, the ratings of baseline videos and videos with genuine laughter reached statistical significance, *p* = .045 < 0.05 one-tailed. See Figure 5.4.

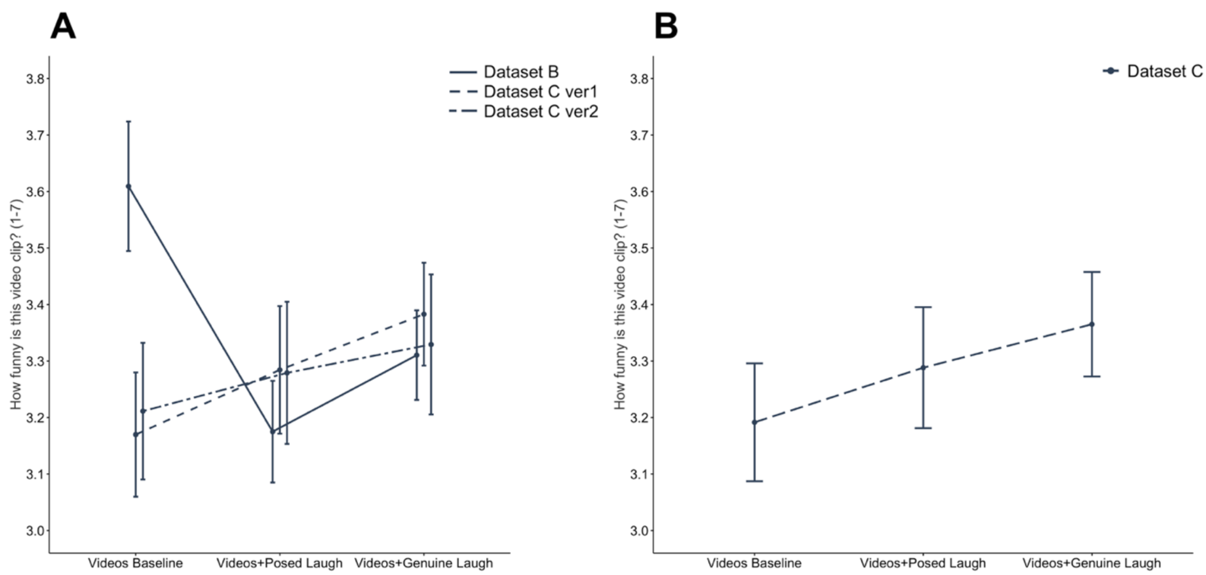


Figure 5.4 Effect of laughter on humour ratings of slapstick videos on the non-autistic participant

Note. Graph A: Effect of genuine and posed laughter on humour ratings of slapstick videos on non-autistic participants in Dataset B (baseline video was silent and was presented as the first block; solid line), Dataset C version 1 (baseline video was paired with non-emotional human vocalization and was fully randomized; dashed line) and Dataset C version 2 (baseline video was silent and was fully randomized; two-dashed line). Graph B: Effect of genuine and posed laughter on humour ratings of slapstick videos on non-autistic participants in Dataset C, combining both versions 1 and 2. Error bars: ± 1 SE in A, B.

5.5.2 Laughter modulation effect on autism group vs non-autistic subgroup

5.5.2.1 Implicit modulation of funniness of jokes by laughter

Firstly, we investigated whether the autism group and NA subgroup differed in the effect that different types of laughter had on the perceived funniness of the jokes in Dataset A. To rule out low-level attentional effects on performance, we compared the number of failed catch trials in the autism group and NA subgroup using an independent samples t-test, which indicated that there was no difference between the groups, $t(48) = 1.080$, $p = .285$, autism: $M = 1.154$, $SD = 1.120$; NA: $M = .833$, $SD = .963$.

A 2 x 2 repeated measures analysis of variance (ANOVA) was conducted, including laughter Type (genuine vs posed) and Group (autism vs NA subgroup) as the within-subject factors. There was a significant main effect of Type of laughter, $F[1,39] = 19.018$, $p < .001$, $\eta_p^2 = .328$, indicating that jokes with genuine laughter ($M = 3.282$, $SD = 0.548$) were rated as more funny than jokes with posed laughter ($M = 3.073$, $SD = 0.534$). There was also a significant main effect of Group, $F[1,39] = 58.075$, $p < .001$, $\eta_p^2 = .598$, indicating that the autistic participants ($M = 3.381$, $SD = 0.555$) rated the jokes as significantly funnier than the NT subgroup ($M = 2.965$, $SD = 0.492$).

There was no significant interaction between laughter Type and Group, $F[1, 39] = .217$, $p = .644$, $\eta_p^2 = .006$, indicating that genuine and posed laughter had the same effect on how funny the jokes were perceived to be by the NA subgroup and autism group (see Figure 5.5).

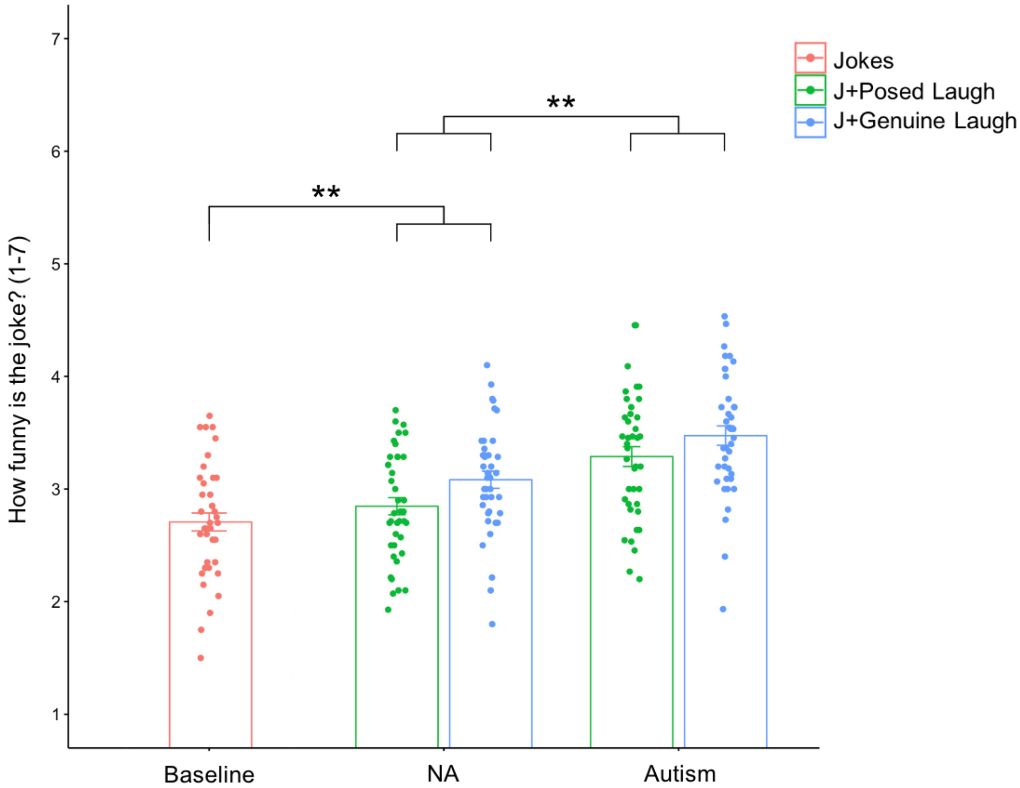


Figure 5.5 Effect of genuine and posed laughter on humour ratings of jokes on the non-autistic and autistic participant in Dataset A

Note. Each dot represents the mean rating of each joke. Error bars: ± 1 SE.

Subsequently, we investigated whether the autism group and NA subgroup differed in the effect that different types of laughter had on the perceived funniness of the jokes by adding the baseline ratings of jokes from a matched group.

Independent-samples Mann-Whitney U tests were used to examine the baseline measures of Meaning ('Do you understand why it's meant to be funny?'), Familiarity ('Have you heard this joke before?') and Mentalizing ('Do you need to consider other people's thoughts and feelings in order to understand this joke?') on the joke stimuli between the NA subgroup and autism group. The results showed no group difference in the number of jokes reported 'No' on Meaning (U = 385.500, p = .588; NA *Mdn* = 4.500, Autism *Mdn* = 3.500) and the number of jokes reported 'Yes' on Mentalizing (U = 512.500, p = .146; NA *Mdn* = 2.500, Autism *Mdn* = 5.500). However, autistic participants were familiar with a significantly higher number of jokes than the NA subgroup (U = 570.500, p = .018 < .05; NA *Mdn* = 2.000, Autism *Mdn* = 4.500). To establish a precise profile of the jokes baseline, an average baseline rating for each joke item is calculated across all the participants only if participants have reported a 'Yes' on its Meaning measure.

As the non-autistic subgroup and autistic group in Dataset B were comparable with the two groups in Dataset A in each group (See Table 5-3). Therefore, we used the baseline data from Dataset B to further investigate whether the autism and NA subgroup differed in the laughter modulation effect on the perceived funniness of jokes. A 2 x 3 repeated measures analysis of variance (ANOVA) was conducted. As we treated each joke as an item, Group (NA subgroup vs autism) and Type of jokes (baseline vs genuine vs posed laughter) were included as within-subject factors. There was a significant main effect of Group, F[1,39] = 101.823, p < .001, η_p^2 = .723, indicating that the autistic participants (M = 3.267, *SEM* = .068) rated all the types of jokes stimuli significantly funnier than the participants in the NA subgroup (M = 2.791, *SEM* = .064). There was also a significant main effect of Type of jokes, F[2,78] = 59.663, p < .001, η_p^2 = .605, following pairwise comparisons with Bonferroni correction indicating that jokes with genuine laughter (M = 3.278, *SEM* = .073) were rated as significantly funnier than jokes with posed laughter (*M* = 3.068, *SEM* = .072; $p < .001$), and jokes with posed laughter were rated as significantly funnier than purely the jokes (*M* = 2.741, *SEM* = .058, $p < .001$) across all the participants. The results also showed a borderline/weak interaction effect between Type and Group, $F[2,78] = 2.842$, $p = .032$ one-tailed, $\eta_p^2 = .068$, indicating that the NA subgroup and autistic group have a subtle difference in perceived funniness of jokes when presented alone or paired with different types of laughter. See Figure 5.6.

Post Hoc analysis was conducted on the laughter modulation effect (Conditions: Posed > Baseline vs Genuine > Baseline vs Genuine > Posed) between two Groups (NA vs autistic). A significant main effect of Type was detected, $F[2,78] = 14.722$, $p = < .001$, $\eta_p^2 = .274$, indicated the laughter modulation effect was different across the three conditions. Laughter modulation on Posed vs Baseline (*M* = .327, *SEM* = .048) and Genuine vs Baseline (*M* = .537, *SEM* = .052) is significantly stronger than laughter modulation on Genuine vs Posed (*M* = .211, *SEM* = .048) across two groups. Also, a significant main effect of Group was found, $F[1,39] = 8.905$, $p = .005 < .01$, $\eta_p^2 = .186$, the laughter modulation effect was generally stronger in the NA group (*M* = .426, *SEM* = .036) than in the autistic group (*M* = .291, *SEM* = .046) across all three conditions. The following analysis indicated a significant difference in the laughter modulation effect between genuine laughter and baseline in two groups, $t(39) = 2.984$, $p = .005 < .01$, the non-autistic group (*M* = .639, *SD* = .345) are strongly influenced by the modulation of genuine laughter than the autistic group (*M* = .436, *SD* = .438). However, the laughter modulation effect between posed laughter and baseline, $t(39) = 1.757$, $p = .087$ (NA: *M* = .403, *SD* = .332; Autism: *M* = .251, *SD* = .475), and laughter modulation effect between genuine and posed laughter, $t(39) = .466$, $p = .644$ (NA: *M* = .235, *SD* = .455; Autism: *M* = .186, *SD* = .454) were comparable between two groups.

The significance level was adjusted using Bonferroni correction for three comparisons (p = .0125).

The line plot (see Figure 5.6) reveals the pattern of implicit laughter processing of jokes in the NA subgroup and autism group. Laughter can influence the perceived funniness of jokes, and the more genuine the laughter, the strongest the modulation effects. However, this tendency was more pronounced among NA participants, driven by their lower ratings of jokes baseline. This suggests that the perceived funniness of the NA group for jokes stimuli was more heavily influenced by the laughter modulation effect than were those of the autism group.

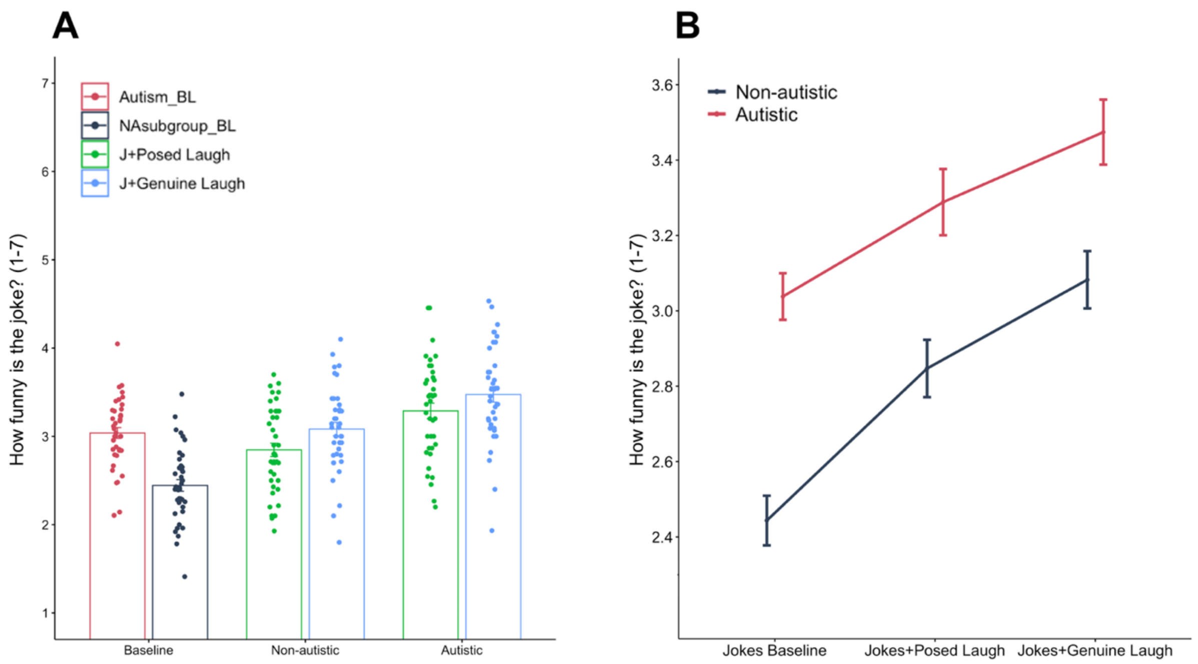


Figure 5.6 Effect of genuine and posed laughter on humour ratings of jokes on the non-autistic and autistic participant in Dataset B

Note. Graph A: Effect of genuine and posed laughter on funniness ratings of jokes with baseline ratings of jokes collected from Dataset B. Graph B: Interaction effect between the type of joke stimuli and group. Each dot represents the mean rating of each joke. Error bars: ± 1 SE.

5.5.2.2 Implicit modulation of funniness of burps by laughter

A 2 x 3 repeated measures analysis of variance (ANOVA) was conducted. As we treated each burp as an item, Group (NA subgroup vs Autism) and Type of burp stimuli (baseline vs genuine laughter vs posed laughter) were included as within-subject factors. There was a significant main effect of Group, $F[1,20] = 40.068$, $p < .001$, η_p^2 = 667, indicating that the autistic group (*M* = 2.781, *SEM* = .051) rated all kinds of burps stimuli as significantly funnier than the NA subgroup (*M* = 2.405, *SEM* = .047). There was no significant main effect of Type, $F[2,40] = 1.652$, $p = .204$, $\eta_p^2 = .076$, indicating that three types of burp stimuli (Burps with genuine laughter: *M* = 2.724, *SEM* = .132; Burps with posed laughter: *M* = 2.704, *SEM* = .141; Burps baseline: *M* = 2.350, *SEM* = .144) were rated as the same funniness level among participants. Finally, there was a significant interaction effect between Group and Type, $F[2,40] = 5.428$, $p < .01$, η_p^2 = .213, indicating that the effect on perceived funniness of presenting burps alone or paired with two types of laughter differs between the NA subgroup and the autistic group.

Post Hoc analysis revealed a significant main effect of Type on the NA subgroup, $F[2,40] = 5.163$, $p = .01 < .05$, $\eta_p^2 = .205$, burps with genuine laughter (*M* = 2.669, *SD* = .577) were rated as significantly funnier than burps presented alone (*M* = 2.080, *SD* = .582; $p < .05$); there was no significant difference between the ratings of burps with genuine laughter (*M* = 2.669, *SD* = .577) and the ratings of burps with posed laughter, and between the ratings of burps with posed laughter (*M* = 2.466, *SD* = .444) and the ratings of burps presented alone. However, the main effect of Type was not significant in the autism group, $F[2,40] = .632$, $p = .537$, $\eta_p^2 = .031$, indicating that burps with genuine laughter (*M* = 2.779, *SD* = .690), burps with posed laughter (*M* = 2.943, *SD* = .902), and burps presented alone (*M* = 2.620, *SD* = .780) were rated as the same funniness level among the autism group.

The main effects of the Group are significant on the ratings of burps presented alone, $F[1,20] = 41.816$, $p < .001$, $\eta_p^2 = .676$, and burps with posed laughter, $F[1,20] = 13.862$, $p = .001 < .01$, $\eta_p^2 = .409$, but not on the ratings of burps with genuine laughter, $F[1,20] = 1.739$, $p = .202$, $\eta_p^2 = .080$. The autism group (*M* = 2.620, *SD* = .780) rated purely the burps significantly funnier than did the NA subgroup (*M* = 2.080, *SD* = .582, $p < .001$), they (*M* = 2.943, *SD* = .902) also rated jokes with posed laughter significantly funnier than did the NA subgroup (*M* = 2.466, *SD* = .444, $p = .001 < .01$). Interestingly, autistic group (*M* = 2.780, *SD* = .690) rated burps with genuine laughter as the same funniness level as did the NA subgroup (*M* = 2.669, *SD* = .577) (see Figure 5.7).

The line plot (see Figure 5.7) reveals the pattern of implicit laughter processing of burps in the NA subgroup and autism group. Laughter can influence the perceived funniness of burps in the NA participants, and that more genuine laughter has the strongest modulation effects. However, this pattern could not be found in the autistic group.

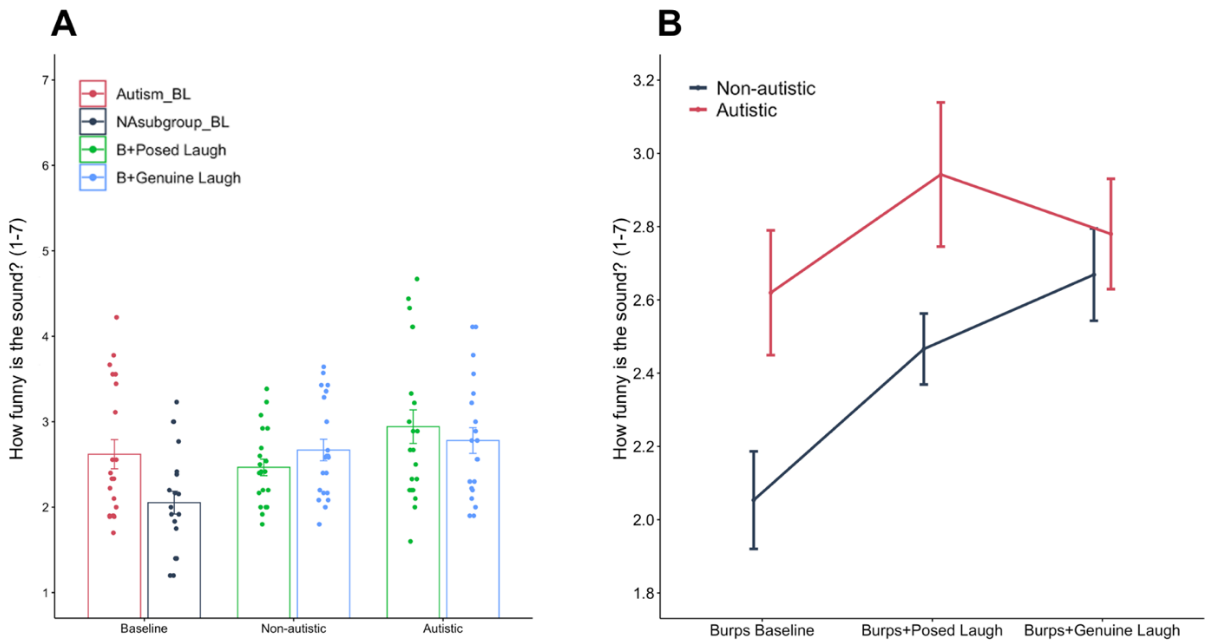


Figure 5.7 Effect of genuine and posed laughter on humour ratings of burp sounds on the non-autistic and autistic participant

Note. Graph A: Effect of genuine and posed laughter on funniness ratings of burps. Graph B: Interaction effect between the type of burp stimuli and group. Each dot represents the mean rating of each joke. Error bars: ± 1 SE.

5.5.2.3 Implicit modulation of funniness of slapstick videos by laughter

In Dataset B, the video task with silent videos first presented as a baseline block was discarded due to its insufficiency of illustrating the tendency of laughter modulation effect on perceived funniness across different types of video stimuli. For this reason, a 2 x 3 repeated measures analysis of variance (ANOVA) was conducted to assess the laughter modulation effect on online video task (Dataset C ver1). As we treated each video clip as an item, Group (NA subgroup vs Autism) and Type of videos (baseline sounds vs genuine laughter vs posed laughter) were included as within-subject factors.

The results showed a significant main effect of Group, $F[1,29] = 73.516$, $p < .001$, $\eta_p^2 = .717$, indicating that the NA subgroup ($M = 3.064$, $SEM = .075$) rated all types of videos as significantly funnier than the autism group ($M = 2.589$, $SEM = .054$). However, there was neither significant main effect of Type, $F[2,58] = 2.161$, $p = .124$, $\eta_p^2 = .069$, nor significant interaction effect between Group and Type, $F[2,58] = .769$, $p = .468$, $\eta_p^2 = .026$ (see Figure 5.8).

The line plot (see Figure 5.8) reveals the pattern of implicit laughter processing of slapstick videos in the NA subgroup and autism group.

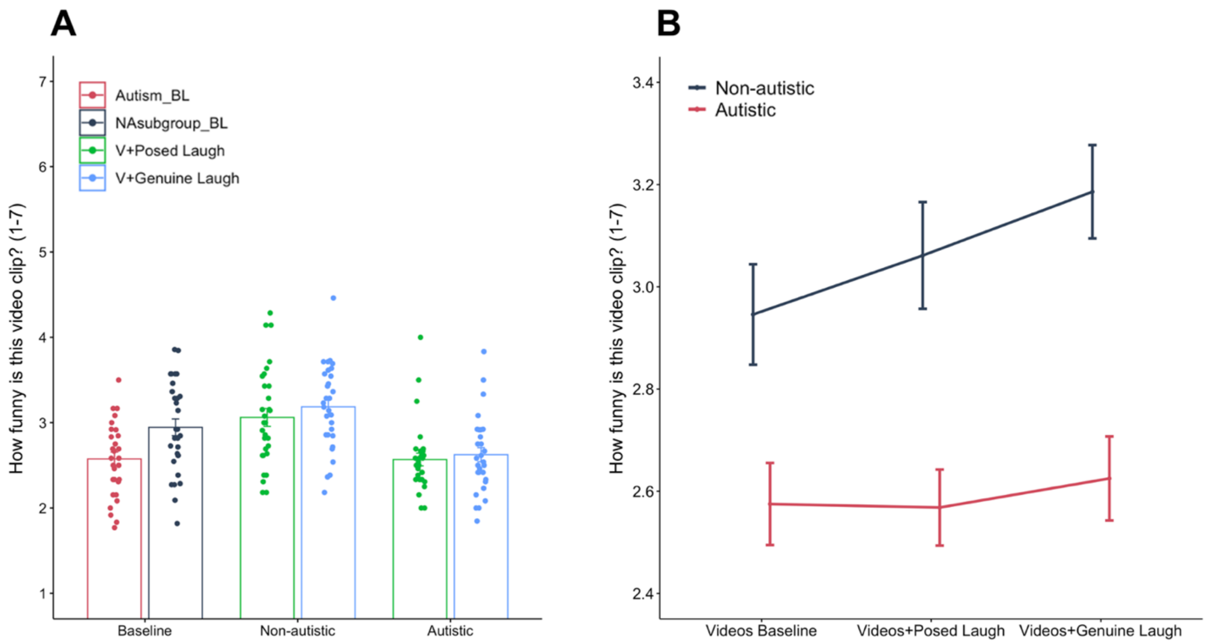


Figure 5.8 Effect of genuine and posed laughter on humour ratings of slapstick videos on the non-autistic and autistic participant

Graph A: Effect of genuine and posed laughter on funniness ratings of slapstick videos in Dataset C ver 1. Graph B: Interaction effect between the type of video stimuli and group. Each dot represents the mean rating of each joke. Error bars: ± 1 SE.

5.6 Discussion and Conclusion

In summary, the current study extended our understanding of implicit laughter processing by adding genuine or posed laughter to a variety of forms of humour stimuli, including puns jokes, burps sounds and slapstick videos, and to see how it affects people's perceived the funniness of humour stimuli to be. In non-autistic adults, the addition of laughter increased the funniness of humour stimuli perceived to be; and they also found the humour stimuli funnier when paired with genuine than posed laughter. Interestingly, the laughter modulation effect was not consistently found in autistic adults: the same laughter modulation effect was found in jokes. However, adding laughter failed to modulate the funniness of burps and slapstick videos. In general, autistic adults with high IQs have a different pattern of implicit processing of laughter relative to non-autistic adults.

5.6.1 Implicit modulation of funniness of humour stimuli by laughter on non-autistic adults

Across all three types of humour stimuli, verbal puns jokes, non-verbal burps, and visual slapstick videos, we found that non-autistic adults rated the humour stimuli funnier when paired with laughter. These findings are in line with previous literature that the presence of laughter enhanced individual perceived enjoyment and pleasure of humour stimuli (e.g. jokes, comedy, cartoons) (Helt & Fein, 2016a; Sumiya et al., 2017, 2020). In addition, we also found an increasing effect on the perceived funniness of humour stimuli when paired with different types of laughter. These findings also support our hypothesis of laughter modulation effect on non-autistic adults. Coincidently, laughter intensity and the degree to which it is strongly positive corrected with humour (McKeown & W., 2016), as we found in Chapter 4 that non-autistic adults rated genuine laughter as significantly more arousal (a similar feature as intensity describing alert and energetic) than posed laughter, which explain why non-autistic adults rated humour stimuli paired with genuine laughter significantly funnier than when it paired with posed laughter regardless of the kinds of humour stimuli. Together, these findings replicated the previous joke study in dataset A, which found other people's laughter influences how funny individuals find humour stimuli (spoken pun jokes) to be, suggesting that the social and emotional meaning of laughter is implicit processing by non-autistic adults, and they cannot ignore the kind of laughter during the implicit processing process.

5.6.2 Implicit modulation of funniness of humour stimuli by laughter on autism and non-autistic subgroup

As we hypothesized, a different pattern of laughter modulation effect on humour stimuli would be detected in the autistic group relative to their NA peers. Our findings indicated that implicit processing of laughter was not consistently found across spoken jokes, non-verbal burps, and visual slapstick videos in autistic adults.

Among spoken jokes, we found a similar profile of implicit processing of laughter in autistic and NA subgroups. As the joke study in dataset A only collected baseline funniness ratings from a separate group of NA individuals, they were not able to investigate whether the effect of pairing puns jokes with laughter on perceived funniness differed between autistic and non-autistic participants. However, with baseline ratings of the funniness of jokes from autistic and a match non-autistic groups, our results replicated the finding, indicating that implicit processing of laughter on spoken jokes has a similar pattern in non-autistic and autistic adults with IQ in the normal range, though non-autistic adults were more heavily influenced by laughter and the types of laughter than autistic adults did.

The different profile of laughter modulation effect on the autistic group was found in perceived humorous of non-verbal burps and visual slapstick videos. As for burps sounds, the addition of laughter increased the perceived funniness in the non-autistic subgroup, but no such effect has been found in the autistic group; namely, autistic adults rated the sound stimuli as the same level of funniness no matter the burps presented alone or paired with laughter. These results may seem incongruous with the joke study in dataset A, the addition of laughter enhanced the perceived funniness of puns jokes, and the types of laughter showed an increasing tendency of funniness in autistic adults.

It is interesting that the presence of laughter increased the funniness of jokes but failed to modulate the funniness of the burps sound among autistic adults. Besides puns/wordplay jokes might be easier for people to get the humour from their semantic context, an alternative explanation is that the nature of jokes and burps convey humour in a very different way. Although both jokes and burps are commonly used in comedy, there is a difference in their nature. While people hold a common sense that jokes are something said to cause amusement or provoke laughter, burps are perceived as funny because they are unexpected and inappropriate behaviour in a social context. Therefore, it is possible that autistic adults may not naturally understand why burps sounds are meant to be funny, and it could be confusing for them when hearing other people laugh at or with burps - a seemingly odd sound. In contrast, as they may already have the concept that people laugh at jokes, they may find it normal and natural when laughter follows, even if they do not understand the jokes themselves.

However, it is not surprising that the autistic group showed a different perceptual pattern during the implicit processing of laughter on burp sounds relative to the non-autistic subgroup. Prior behavioural evidence has demonstrated differences in the processing of laughter in autism; autistic children seem to process laughter differently from their typically developing peers, as they generally find cartoons with a laughter track less enjoyable compared with cartoons presented alone. In addition, autistic children found laughter less contagious (Helt & Fein, 2016a) and show greater sensitivity to task context and familiarity with the laughter (Helt et al., 2020). In another study, it was found that autistic adults experienced less pleasure from jokes when they were followed by group laughter compared to their neurotypical peers (Sumiya et al., 2020). From a perspective of neuroimaging, previous research indicated the engagement of mentalizing during laughter processing, especially in differentiating between genuine and posed laughter (McGettigan et al., 2015). There is a large body of evidence supporting the theory that autism is characterised by difficulty in mentalizing (Baron-Cohen et al., 1985; C. D. Frith & Frith, 2006; White et al., 2014). We further found that autistic adults were less well at differentiating these two types of laughter, they particularly perceived posed laughter as more alike genuine laughter among several affective properties in an explicitly processing task in Chapter 4. Therefore, autistic adults are less influenced by the presence of laughter, no matter the burps paired with genuine or posed laughter.

Regarding the slapstick videos task, we found that the perceived funniness of slapstick videos had no difference when videos were presented alone or paired with laughter; additionally, this perceptual pattern is the same among autistic and non-autistic subgroups. Although we detected a significant main effect of types of laughter in the larger non-autistic sample, it is important to notice that only the ratings of videos with genuine laughter and baseline (videos presenting alone) reached statistical significance. In comparison with the modulation effect on jokes and burps, this finding indicated that laughter and the types of laughter generally have a weaker modulation effect on slapstick videos. There are several reasons to explain our current findings. Firstly, unlike sitcoms commonly filled with laughter tracks, slapstick videos are black-and-white comedy films with long-running silence, our participants may not expect to hear other people's laughter while watching them. Secondly, adding laughter (an audio clip) at the end of auditory stimuli (jokes and burps) is perceived as more natural than using laughter to manipulate the funniness of visual stimuli. Also, the ratings of funniness of the combination of visual and auditory stimuli are largely influenced by how the baseline visual stimuli are present rather than the timing of laughter is present. It is clear that more future work is expected to be done in this area to explore the effect of adding laughter to manipulate the funniness of visual stimuli.

Interestingly, we also found that the autistic group rated all the jokes and burps stimuli (presenting alone and with laughter) as funnier than the non-autistic subgroup. However, an opposite rating pattern was found in the slapstick videos task, non-autistic rated all the video stimuli as funnier than the autistic group. This may be due to autistic groups being from distinct sources, which reflects a different pattern in using the rating scale. Both the ratings of jokes and burps were from the in-lab sample, and the video task was from an online sample. Our in-lab autistic participants were more generous than non-autistic participants in giving higher ratings to uncool jokes and silly burps, whilst the online autistic participants were more conservative than non-autistic participants.

In conclusion, the addition of laughter increased the funniness of humour stimuli perceived to be in non-autistic adults; and they also found the humour stimuli funnier when paired with genuine than posed laughter. However, relative to non-autistic adults, autistic adults with high IQs have a different pattern of implicit processing of laughter across various humour stimuli.

5.7 Appendix 5A

Table 5-5 Details of the jokes. (Cai et al., 2019)

Number	Jokes
1	What do you call a bear with no socks on? Bare foot.
2	What button is impossible to unbutton? The belly button.
3	What did Michael Jackson call his denim store? Billie Jeans.
4	What is invisible and smells of worms? A bird's fart.
5	What do you call a Minecraft celebration? A block party.
6	Who is the best Kung Fu vegetable? Brocc-Lee.
7	What do you call a rabbit who is angry over getting burnt? A hot cross bunny.
8	What did the butt say to the other butt? PTTTTT <raspberry noise>.
9	What's orange and sounds like a parrot? A carrot.
10	Why couldn't the toilet paper cross the road? He got stuck in a crack.
11	What's round and sounds like a trumpet? A crumpet.
12	What do you call a sleeping dinosaur? A dino-SNORE.
13	What do you call a man with a spade on his head? Dug.
14	What kind of hair do they sell at IHOP? Eggstensions.
15	What do you call an Asian man who always has correct change? Exact Lee.
16	What do you call an apple that farts? A fruity Tooty.
17	What is the best day to cook? FRY-DAY.
18	What did the horse say when it fell? GIDDYUP!
19	What do you receive when you ask a lemon to help? Lemon aid
20	Why can’t you give Elsa a balloon? Because she will let it go.
21	When does a sandwich cook? When it is bakin' lettuce and tomato.
22	Why did the smart phone need glasses? It lost all its contacts.
23	What state has the smallest drinks? Mini-soda.
24	Why did the cow cross the road? They wanted to go to the mooooovies.
25	What do you call a funky car? Mustang.
26	What did the hammer say to his homeboys? Nailed it.
27	Why are cats good at video games? Because they have nine lives.
28	What do you call a deer with no eyes? No idea.
29	What is big and green and falls off over the tree will kill you? A snooker table.
30	What did the French guy do when he drank too much water? He went oui oui in his pants
31	Where do pencils spend their vacation? Pencil-Vania.
32	What do flies eat for breakfast? A bowl of poop loops.
33	Why did the balloon go near the needle? He wanted to be a pop star.

34	What did the duck do when he read all these jokes? He quacked up.
35	Why was the tomato all red? It saw the salad dressing.
36	What do you call a female magician in the dessert? A sand witch.
37	How do billboards talk? Sign language.
38	What is brown and sticky? A stick.
39	I hurt my foot driving the other day. You know what I called? The toe company.
40	What does a dinosaur use to pay bills? Tyrannosaurus checks.

Chapter 6. Does Laughter Make Things Funnier? An fMRI Study from a Neurodiversity Perspective.

6.1 Abstract

Laugher can be spontaneous emotional vocalisations or serve as social signals in daily interaction. A previous neuroimaging study found that non-autistic adults automatically engage in high-level cognitive skills, such as mentalising ability, to understand and interpret the intention and meaning behind laughter. Intriguingly, the social and emotional meaning of laughter is processed implicitly by participants: genuine laughter has been found to amplify the funniness of humour stimuli (e.g., jokes) more than posed laughter amongst both non-autistic and autistic adults. However, there have been no studies researching whether autistic adults have a different neural mechanism of implicit laughter processing relative to neurotypical adults and, if so, how it relates to their mentalising difficulties. To address the above questions, we asked autistic and non-autistic adults (comparable for age, gender and IQ) to passively listen to funny words paired with genuine laughter, posed laughter or baseline stimuli (noise-vocoded human vocalisations) in an fMRI study. In the ROI analysis, we found non-autistic participants showed greater activation in the medial prefrontal cortex (mPFC) than autistic adults during implicit processing of posed laughter versus genuine laughter, but not in autistic adults, and reduced discrimination between these laughter types in autistic adults. Overall, our findings indicate the medial prefrontal cortex and sensorimotor cortex to be crucially involved in the implicit processing of laughter, especially highlighting the engagement of the medial prefrontal cortex and mentalising in the implicit processing of posed and communicative laughter.

6.2 Introduction

Although laughter research is still being in its infancy, there are emerging studies using fMRI to understand the perception of human laughter. Some of them found that this process involved higher-order cognitive networks, such as mirroring and mentalising networks (Lavan et al., 2017; McGettigan et al., 2015; Scott et al., 2014; Warren et al., 2006).

Using laughter produced by professional actors under certain emotional states by means of imagination and emotional recall in its design, Szameitat et al. (2010) found higher activations in the anterior rostral medial frontal cortex (arMFC) during the perception of emotional laughter (e.g., joyful and taunting laughter), whereas stronger engagement in the right superior temporal gyrus (STG) during the processing of tickling laughter in neurotypical participants. In a following brain connectivity study with the same laughter stimuli, Wildgruber et al. (2013) found that laughter with a higher degree of complex social meaning (emotional laughter vs tickling laughter) was associated with increases in connectivity between auditory association cortices, the right dorsolateral prefrontal cortex and brain areas associated with mentalising as well as areas in the visual associative cortex. These findings reflected the increasing demands on social cognition processes during perceiving emotional laughter, such as decoding social information in laughter.

Another study selected laughter samples from the internet and let neurotypical participants watch visual jokes with their punchline inside the scanner: they either read the punchline aloud or listened to another person read the punchline, following with laughter sound (group laughter, single laughter, no laughter) as a social rewarding cue. Although the author found listening to self-relevant responses (participants read the punchline) showed stronger activation in the medial prefrontal cortex (mPFC) compared to self-irrelevant responses (participants listen to punchline). However, they also found greater activation in the mPFC when participants heard group laughter versus single laughter by converging self-relevant or self-irrelevant conditions (Sumiya et al., 2017). In a follow-up study, Sumiya et al. (2020) examined the same paradigm on neurotypical and autistic adults. Again, stronger activation in arMPFC was detected in neurotypical adults in self-relevant responses, and this activation was attenuated in autistic adults. Although the author's primary interest was not the brain activation of the manipulation of laughter, however, in the ROI analysis, only receiving 'single laughter' showed the difference of activation in arMPFC between groups (neurotypical > autism). Interestingly, no group difference has been found in arMPFC while participants received 'no laughter' and 'group laughter' as social rewarding cues/outcomes (Sumiya et al., 2020).

All the above-mentioned studies found greater activation in mPFC results from greater engagement of social cognition processes (e.g., mentalising, self-related activity) while trying to determine the emotions and intentions of others in perceiving laughter. However, these studies did not take a critical point into account while examining the perception of laughter: whether the laughter is under voluntary control. Since involuntary (genuine) and voluntary (posed) laughter is acoustically distinct, and recruit different production systems (Wattendorf et al., 2013; Wild et al., 2003), it is important to understand the underlying perception system. To date, only a few studies examine the difference between processing genuine and posed laughter by using fMRI.

Warren et al. (2006) demonstrated that passive listening to positive or highly arousing emotions (e.g., a mixture of spontaneous and deliberate laughter) involves the auditory-motor mirror network of the premotor cortex and the pre-supplementary motor area (SMA), suggesting a fundamental mechanism for understanding the intention and mirroring the emotional states of others during human social behaviour.

McGettigan et al. (2015) further investigated the neural responses whilst passively listening to spontaneous/authentic and deliberate/posed laughter in neurotypical adults. They found greater activity in superior temporal gyri (STG) when listening to genuine than posed laughter. Interestingly, greater activation has been found in the anterior medial prefrontal cortex (amPFC; Brodmann's area 10) and anterior cingulate cortex (ACC) when listening to posed laughter than genuine laughter. In addition, the performance of the participant's authenticity judgement of laughter was strongly predicted by individual activation of amPFC area during the scan session. These findings indicated 'an obligatory attempt to determine others' mental states' (McGettigan et al., 2015, p. 1) during the perception of volitional (posed and communicative) laughter.

In a follow-up study, Lavan et al. (2017) conducted parametric modulation to explore the relationship between neural correlates of passive perceiving genuine and posed laughter and participants' affective ratings of these two types of laughter. Similar to the previous study, they found the activation of amPFC showed negative linear correlations with authenticity and valence ratings of genuine and posed laughter. Together, the involvement of mPFC suggests that laughter perception, especially the processing of posed and voluntary laughter, automatically engages people's mentalising ability to understand and interpret the social ambiguity, such as the intention and meaning behind the laughter.

6.2.1 The present study

In previous chapters, we found behavioural evidence of differences in the explicit and implicit processing of laughter between non-autistic and autistic participants. In general, relative to non-autistic adults, autistic adults with high IQs showed lower discrimination of genuine and posed laughter no matter in the explicit ratings of its affective properties or implicitly perceived the funniness of humour stimuli by using the laughter modulation paradigm. However, the underlying neural mechanism of this process is unclear.

Therefore, we conducted an fMRI study by adapting the implicit laughter processing paradigm in Chapter 5 to investigate A) the underlying neural mechanism of implicit laughter processing between autistic and non-autistic adults. To shorten the duration of the scan, we used funny words instead of pun jokes in the design. In addition, we selected noise-vocoded human vocalisation; human vocalisation does not sound emotional and contagious anymore after noise-vocoded, as baseline sound stimuli to compare with the laughter modulation effect of two types of laughter.

As we know, autistic people have difficulties in mentalising ability, and there is experimental evidence showing the difference between neurotypical and autistics in the neural correlation of mentalising, especially in recruiting mPFC (C. D. Frith & Frith, 2006; Gilbert et al., 2006, 2009; White et al., 2014). Therefore, we are mainly focused on B) how the implicit laughter processing relates to difficulties in mentalising ability, namely the engagement of the mPFC area (BA10). Particularly, an implicit mentalising localiser was implemented in the fMRI design to specify the activation in our prior area. In addition to the fMRI session, participants also completed a pre-scan implicit mentalising eye-tracking task and a post-scan implicit laughter processing task to associate the performance difference in behavioural and brain levels.

Given the difficulty of social communication and mentalising ability in autism, we hypothesised differences in the implicit processing of laughter would be found in the neural correlation in the mPFC area between autistic and non-autistic adults. Specifically, for non-autistic adults, we hypothesised that greater activation would be found in the mPFC area during the implicit processing of posed laughter than genuine laughter. However, reduced discrimination between these laughter types would be found in autistic adults. Regarding their performance in the behavioural task, we hypothesised that there would be a subtle difference in the implicit processing of laughter on funny words between the two groups, which is in line with the findings in Chapter 5. We would expect an increasing effect of laughter modulation (No laugh < Posed Laugh < Genuine Laugh) of the funniness of words in the non-autistic group, however, this effect is likely to be smaller in the autistic group.

6.3 Method

6.3.1 Participants

In total, 25 autistic adults and 23 non-autistic adults participated in this study. All the participants were right-handed, had normal or corrected-to-normal vision, and had no speech, hearing or neurological difficulties. Only one autistic participant, along with a comparable non-autistic participant, were fluent in English, while all other participants were native English speakers. Non-autistic participants were recruited via Autism@ICN and UCL SONA subject database. In addition to the abovementioned subject datasets, autistic participants were also recruited through advertisements to Cambridge University Autism Research Centre (ARC) and several university disability services in the United Kingdom. Informed written consent was obtained prior to testing, and the project received approval from the UCL research ethics committee.

All participants in the autism group received an official diagnosis issued by a qualified clinician. Three of them also reported diagnoses of attention deficit hyperactivity disorder (ADHD) or/and attention deficit disorder (ADD). Unfortunately, we were not able to administer ADOS (Hus & Lord, 2014) to verify their diagnosis due to testing restrictions during the COVID-19 pandemic. Therefore, participants were required to complete the Autism Spectrum Quotient (AQ; Baron-Cohen et al., 2001) in the pre-screening assessment prior to testing. For non-autistic participants, an AQ score below the recommended cut-off of 32 was used as an inclusion criterion.

The groups were comparable for gender ($\chi^2(1) = .060$, $p = .807$), age ($t(46) = -.134$, $p = .894$), and verbal ($t(46) = .720$, $p = .475$), performance ($t(46) = -.875$, $p = .386$), and full-scale IQ ($t(46) = .031$, $p = .975$) as measured by four subtests of the Wechsler Adult Intelligence Scale (WAIS-IV UK; Wechsler, 2008; Matrix Reasoning; Block Design; Similarities; Vocabulary). And the groups differed on AQ, $t(46) = -11.879$, $p < 0.001$. However, two autistic males were unable to complete the scan due to health and technique issues. The groups were remain comparable for gender ($\chi^2(1) = .000$, $p = 1.000$), age ($t(44) = -.258$, $p = .798$), and verbal ($t(44) = .392$, $p = .697$), performance ($t(44) = -1.123$, $p = .268$), and full-scale IQ ($t(44) = -.303$, $p = .763$). And the groups differed on AQ, $t(44) = -12.325$, $p < 0.001$ (See Table 6-1).

Table 6-1 Participant Demographic Information

	NA	**Autism**	**Autism for scan**
N (male: female)	23 (13:10)	25 (15:10)	23 (13:10)
Age (years)	28.348 (9.203)	28.720 (9.969)	29.087 (10.238)
Verbal IQ	121.435 (15.048)	117.800 (19.416)	119.435 (19.315)
Performance IQ	109.478 (15.985)	113.560 (16.289)	114.783 (16.059)
Full Scale IQ	119.000 (15.895)	118.840 (19.429)	120.565 (19.023)
AQ	13.652 (5.928)	35.560 (7.292)	37.348 (7.062)

Note. Values are given as mean (standard deviation), except when otherwise stated. NA = non-autistic; AQ = autism-spectrum quotient. All the p-value were reported in two-tailed.

6.3.2 Experiment Procedure

The whole experiment lasted approximately 4.5 hours, including the pre-scan behavioural session (implicit mentalising eye-tracking task), the post-scan behavioural session (implicit laughter processing task and WAIS testing), and the scan session. Pre- and post-behavioural sessions were around 3 hours and conducted at the

Institute of Cognitive Neuroscience. The scan session was around 90min and took place at Birkbeck-UCL Centre for Neuroimaging. The stimuli, materials and design of the abovementioned task sessions are described in chronological order of the testing in the following section.

Before going into the scanner, the participants were informed that they would undertake five tasks in total, and each task will take around 15 minutes. The first task will be the video-watching task (implicit mentalising localiser). Following by four sound perception tasks (implicit laughter processing). There will also be a few short scan sequences for testing volume and taking an image of the brain. The structural scan would be performed halfway through the scan, right after the video-watching task and two sound perception tasks. Participants were given clear instructions about the tasks, and they were not aware that the stimuli would be laughter and the laughter varied in terms of authenticity.

6.3.2.1 Pre-scan behavioural session: Implicit mentalising eye-tracking task

The implicit mentalising eye-tracking task was a modified version base on the previous paradigm (Senju et al., 2009). This 20-minute task consists of 24 video clips (details are given below), and the videos were displayed by Tobii Studio (Version 3.4.8.1348, Tobii Technology) on a DELL Precision 5530 laptop (16.5-inch screen). During watching the videos, the eye movement of each participant (e.g., areas of interest, the direction of gaze, etc.) was tracked and collected by Tobii Pro X3-120 eye tracker (120 Hz sampling rate, used with Tobii Pro X3-120 External Processing Unit, Stockholm, Sweden).

The video series includes 8 familiarisation (Fam) trials, 8 false belief (FB) and 8 true belief (TB) trials. Instruction screens appeared after the first and last trial, and there was a 0.6-second inter-trial interval featuring a black screen. There was no speech featured and each trial had a similar scene: a female agent stood behind a panel which had two windows on it so that the agency could retrieve a colourful ball from the opaque boxes under it. The agent wore a cap which covered her eyes to avoid participants would focus on her eyes and the direction of her gaze rather than her actions.

The videos in Fam trials were aimed to familiarise participants with the elements of the scene, understand the cover story of the task, and thus create an association between the audio-visual cue (a simultaneous light and a simultaneous bell-chime) and the agent's action to reach through one of the windows and retrieve the ball. The ball either A) move by a puppet and is placed in one of the boxes or B) initially is above one of the boxes. In two versions of the scene, the audio-visual cue is played, and subsequently, the agent reaches through the windows to A) open the box and retrieve the ball or B) reach the ball on the box. If familiarisation was successful, it would elicit an anticipatory-looking response at one of the windows at the sound of the audio-visual cue, without the agent moving at all.

The videos in FB trials were designed to elicit mentalising. The agent is watching the puppet moves the ball from one box to the other. Simultaneously, the direction of her head movements follows the puppet. A doorbell rings so that the agent looks away from the scene, indicating she is no longer paying attention to the puppet's actions. The puppet then moves the ball a second time, resulting in the agent's false belief about the ball's location. Participants can then hear the door closing, and the agent turns back to look at the scene. The audio-visual cue is displayed, and the trial ends 5 seconds later. Participants who are able to successfully implicitly mentalise would be able to correctly attribute a false belief to the agent in the video and subsequently look towards the box that she would think the ball was placed in, based on the false belief of the agent.

The videos in TB trials were designed as a control condition providing the baseline measure of the eye-tracking pattern. A doorbell rings after the puppet moves the ball. However, the actress shakes her head, indicating that she is ignoring what happened and continues to watch the puppet's actions. The puppet then moves the ball a second time, resulting in a true belief about the ball's location. At this point, the sound of a car driving away is displayed, and the agent looks away as if watching the car. The audio-visual cue is displayed, and the trial ends 5 seconds later. However, this time as the agent was observing the movement of the puppet for the whole trial, there was no false belief created. The true belief trials do not require mentalising, but participants are expected to look in the direction of where they would expect the agent to search for the ball. (See Figure 6.1).

The experimental trials (TB and FB trials) were counterbalanced by the ball location, the agent's head turn, and the turn of the puppet. In addition, the sequence of the video was presented as follows: 5 Fam trials, 4 experimental trials, 1 Fam trial, 4 experimental trials, 1 Fam trial, 4 experimental trials, 1 Fam trial, 4 experimental trials. The presented orders of the video stimuli were pseudo-randomised and counterbalanced across participants.

Before starting the task, participants were asked to adjust their seating position and sit directly in front of the laptop. Their seat was placed around 70-72cm from the laptop, and the participants were told to stay as still as possible during the task. The eye tracker was calibrated for each participant. The participant was asked to start the task only after successfully passing through the calibration. Then the experimenter left the room and watched in a separate room through a visual channel.

6.3.2.2 Scan session: Implicit Mentalising Localiser

Stimuli consisted of 8 trials of FB video and 8 trials of TB videos, and the video stimuli were presented without sound. Participants did not watch the Fam trials again since they were familiar with the cover story in the pre-scan session.

At the beginning of each trial, a written sign “Get Ready” was presented on the screen for 2 seconds. Following the presence of video stimuli, each video stimulus lasted approximately 45 seconds and was followed by an inter-trial interval (ITI) of 12 seconds with a fixation cross displayed on the screen. The 16 video stimuli were randomly present. The task was presented using MATLAB (version R2018b, Mathworks, Sherborn, MA, USA) and the psychophysics toolbox (Brainard, 1997; Pelli, 1997; Kleiner et al, 2007). Before the scan, participants were informed that this video-watching task was the first task and that they were going to watch some of the videos in the pre-scan session, but this time the videos would remain silent. And this task sequence is around 15 minutes (see Figure 6.1).

A continuous event-related fMRI was employed. Images of blood-oxygen-level-dependent (BOLD) changes were acquired with a Siemens Avanto 1.5-Tesla MRI scanner (Siemens AG, Erlangen, Germany), using a 32-channel head coil. Functional imaging data were acquired. Video presentation of the implicit mentalising task took place in 1 run of 323 echo-planer whole-brain volumes (TR = 3s; TE = 50ms; TA = 86ms; Slice tilt = 25 ± 5 degrees; flip angle = 90°; 3 mm × 3 mm × 3 mm in-plane resolution). A mirror was placed over the head coil to enable the participant to watch videos on the screen.

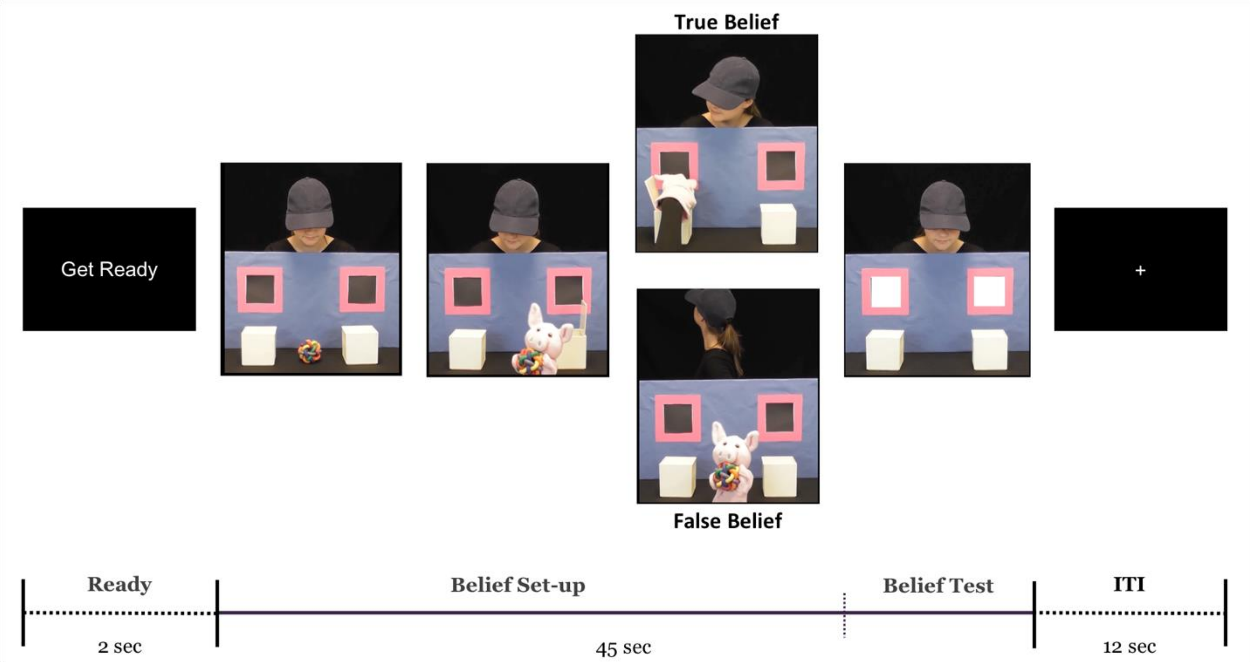


Figure 6.1 Trial structure and conditions in the implicit mentalising localiser

Note. Examples of true belief condition (up) and false belief condition (bottom). Trials started with the ball placed in the middle of two boxes, and the agent witnessed the puppet move the ball. When the doorbell rings (silent inside the scan), the agent either ignores the doorbell and continues to observe the puppet moves the ball inside a random box (true belief; Up), or the agent turns back and is not observing the puppet move the ball inside a random box (false belief; Bottom). Followed by a visual cue displayed to indicate the agent is about to make a decision.

6.3.2.3 Scan session: Implicit Laughter Processing

Word Stimuli. A list of 300 words was selected from (Engelthaler & Hills, 2018). The original pool contains 4997 words, and each word was visually presented and rated by participants for its funniness on a 5-point Likert scale from 1 (humourless) to 5 (humorous). To avoid the floor effect, we first selected 719 words with a humour rating higher than 2.8. Next, these 719 words were further annotated by four native English speakers to screen for appropriateness, resulting in a list of 621 words. The 621 words were audio recorded by a professional male comedian in a comedy performance style. The raw audio file was downsampled at a rate of 44100 Hz to mono.wav files with 32-bit resolution and each word was trimmed and edited into a 1-second sound file (.wav) using version 2.3.3 of Audacity(R) recording and editing software. The files were then normalised for root-mean-square (RMS) amplitude using PRAAT (Boersma & Weenink, 2014).

A pilot study was further conducted to establish the baseline funniness ratings of the 621 audio words. The words were assigned to three lists, each list contained 207 words. The three lists were matched on their humour ratings from a previous study (List 1: M = 3.19, SD = 1.23; List 2: M = 3.20, SD = 1.23; List 3: M = 3.18, SD = 1.23) (Engelthaler & Hills, 2018). Fifty-eight native-English speakers were randomly assigned to one of the three lists (list 1 n = 18; list 2 n = 19; list 3 n = 21). Participants were instructed to listen to the recordings of Ben, a comedian, performing some funny words. They were asked to rate the funniness of each word on a 7-point Likert scale ("How funny was the word the way that Ben said it?" 1-Not funny at all, 4-Neutral, 7-Extremely funny) and indicated whether they understand the meaning of that word. There was a practice trial before the real task. The task was built and presented via Gorilla Experiment Builder (www.gorilla.sc; Anwyl-Irvine et al., 2020).

The final 300 words were selected from the results of the above pilot study after avoiding floor and ceiling effects. The funniness ratings of the words Mean = 3.309, SD = .586. The intelligence of the words Mean = 92.959%, SD = 10.619%. The acoustic features of the 300-word stimuli were extracted by PRAAT. The duration of word stimuli Mean = .736 seconds, SD = .225 seconds, the root-mean-square Mean = .031, SD = .000, the pitch Mean = 189.677 Hz, Median = 168.646 Hz, SD = 82.154 Hz.

Sound Stimuli Set. The sound stimuli set contained 50 genuine laughter (GL), 50 posed laughter (PL) and 50 no emotional and no contagious (NE) sound clips. All 150 sound stimuli were then normalised for root-mean-square (RMS) amplitude using PRAAT (Boersma & Weenink, 2014).

- The laughter stimuli were selected from the emotional vocalisation dataset recorded from a previous study (see Chapter 4 for a detailed account). All 50 genuine (involuntary) and 50 posed (voluntary) laughter stimuli were used in the current fMRI study.
- The NE stimuli were 50 single-channel noise-vocoded human vocalisations. The original emotional vocalisations contained a combination of human vocalisations, such as anger, pleasure, disgust, surprise etc. However, these human vocalisations do not sound emotional and are contagious to the normal-hearing listener after noise-vocoded.

A range of acoustic parameters was extracted on sound stimuli set by using PRAAT (Boersma & Weenink, 2014). One-way ANOVA indicated that genuine laughter, social laughter and NE sound stimuli were comparable in duration, $F(2,147) = 1.297$, $p = .276$ (genuine, M = 2.376, SD = .406; social, M = 2.269, SD = .361; NE, M = 2.307, SD = .216), root-mean-square (RMS), $F(2,147) = .908$, $p = .406$, and intensity, $F(2,147) = .945$, $p = .391$. However, genuine laughter and social laughter were significantly different in pitch (Pitch: genuine, M = 389.006 Hz, SD = 90.403, social, M = 279.970 Hz, SD = 86.785, $t(98)=7.801$, $p < .001$; Median pitch: genuine, M = 389.837 Hz, SD = 77.780, social, M = 264.612 Hz, SD = 68.871, $t(98) = 8.522$, $p < .001$), spectrum centre of gravity (Hz) (genuine, M = 1221.347 Hz, SD = 459.698, social, M = 926.435 Hz, SD = 269.498, $t(79.123) = 3.913$, $p < .001$), jitter (local) (genuine, M = 2.952 Hz, SD = .951, social, M = 3.955 Hz, SD = .776, $t(98) = -5.780$, $p < .001$), shimmer (local, dB) (genuine, M = 1.215 Hz, SD = .284, social, M = 1.343 Hz, SD = .252, $t(98) = -.390$, $p < .05$), and Mean harmonics-to-noise ratio (HNR) (genuine, M = 7.752, SD = 2.753, social, M = 5.836, SD = 1.844, $t(85.597) = 4.098$, $p < .001$). They were matched on duration (genuine, M = 2530 msec, SD = .385; posed, M = 2382 msec, SD = .362) and other measures — root-mean-square (RMS), intensity (dB), the standard deviation of pitch (Hz), spectral standard deviation (Hz), and the fraction of locally unvoiced frames.

Design. An event-related paradigm is employed in the fMRI experiment. The study investigated whether the addition of different types of sound stimuli (GL/PL/NE) would modulate the perceived funniness of words, the design was adapted from the prior Implicit modulation of funniness of humour stimuli by laughter task (see Chapter 5 for details).

There were four functional runs in total. Each run lasted approximately 14 minutes and contained 105 trials in five experimental conditions (GL, PL, NE, REST, VIG). Within each trial, a jittered inter-trial interval (ITI) based on normal distribution ranging from 2 to 4 seconds was randomly presented. In the trials of GL, PL and NE conditions, a funny word was presented (Mean = .74 seconds), followed by a GL/PL/NE stimulus (Mean = 2.3 seconds) with a fixed duration of inter-stimulus interval (ISI) for 0.09 seconds. In the REST trials, 2 seconds silence period was presented after ITI. In the VIG trials, 0.5 seconds of beep sound were presented, and then participants had up to 3 seconds to press a button.

While in the scanner, each participant was presented with 300 words paired with 50 genuine laughter (GL), 50 posed laughter (PL) and 50 NE stimuli (NE) across four runs. The sound stimuli set (GL/PL/NE) was used twice during the whole scan. In each run, participants passively listened to 25 trials in GL, 25 trials in PL, 25 trials in NE, and 25 trials in REST condition. Additionally, 5 VIG trials were presented to test whether the participant was awake and paying attention to the task in each run. See Figure. 6.2.

Trials in the five conditions and all possible pairings (words paired with sound stimuli) were pseudorandomised and counterbalanced across the four functional runs and across participants by custom-built pseudorandom order and stimuli lists generated by Matlab. However, the randomisation of the trial conditions was conducted under certain criteria: three consecutive trials were never the same condition, the first trial of each run was never the REST condition or the VIG condition (i.e., beep sound); and the RRST and VIG conditions never followed each another.

A continuous event-related fMRI was employed. Images of blood-oxygen-level-dependent (BOLD) changes were acquired with a Siemens Avanto 1.5-Tesla MRI scanner (Siemens AG, Erlangen, Germany), using a 32-channel head coil. Cushions were used to restrict head movement. Presentation of the implicit laughter experiment was completed in four runs of 260 echo-planer whole-brain volumes (TR = 3s; TE = 50ms; TA = 86ms; Slice tilt =25 ± 5 degrees; flip angle = 90°; 3 mm × 3 mm × 3 mm in-plane resolution). Auditory stimuli were presented via Sony STR-DH510 digital AV control centre (Sony, Basingstoke, UK) with an MR-compatible insert earphone (Etymotic Research, Inc., Elk Grove Village, IL). The experiment was designed and presented using MATLAB (The MathWorks, Natick, MA, USA) and the psychophysics toolbox (Brainard 1997; Pelli 1997). The total duration of four runs was approximately 56 minutes.

Before the scan, participants were informed that they would complete a passive sound perception task after the video-watching task. This task contains four sessions; they would listen to recordings of funny words spoken by an amateur comedian and other people's responses to his performance. Additionally, participants were instructed to press a button on a button-box when they heard a "beep" sound. Experimenters intentionally avoided mentioning the task was about laughter modulation. Inside the scanner, before starting the laughter task, there would be a short practice sequence to test the volume and participants were asked to recall the words they had heard to make sure they could hear the stimuli clearly.

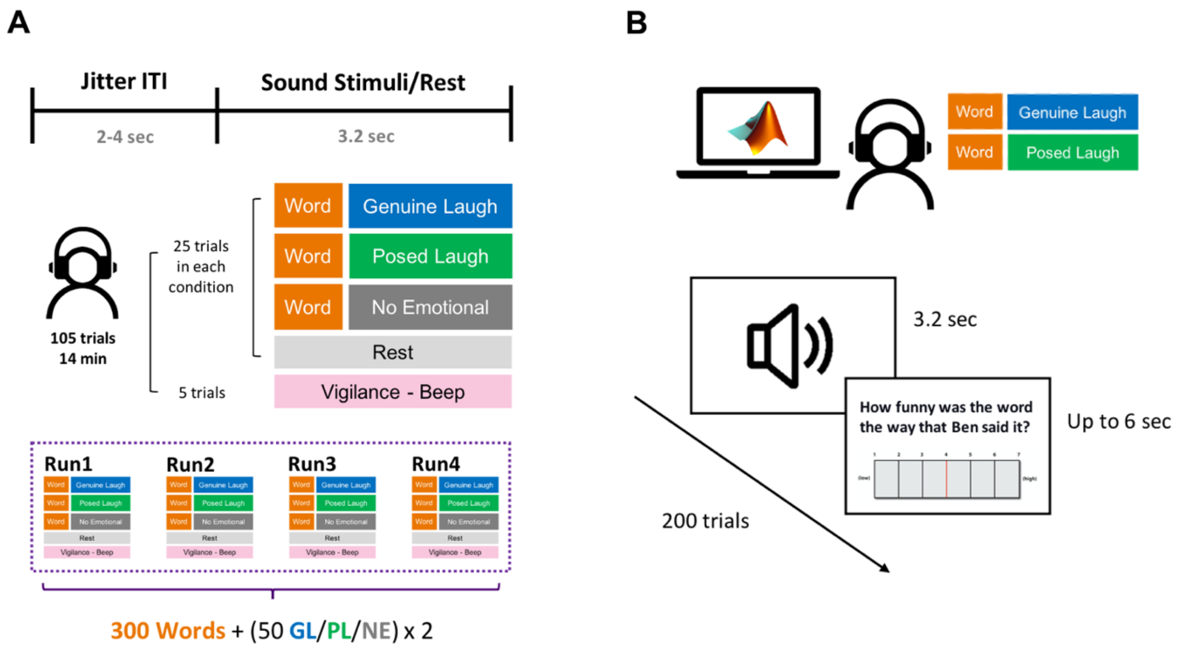


Figure 6.2 Experimental design of A) implicit laughter processing task and B) post-scan behavioural laughter rating task

6.3.2.4 Scan session: Structural scan

After the two runs of the laughter task, high-resolution anatomical images were acquired using a T1-weighted magnetisation prepared - rapid acquisition gradient echo sequence (MPRAGE; 176 sagittal slices, TR = 2730ms; TE = 3.57ms; flip angle = 7°, acquisition matrix = 224 × 256 × 176, slice thickness = 1 mm, 1 mm x 1 mm x 1mm).

6.3.2.5 Post-scan behavioural session: Implicit laughter rating task

After the scanning session was complete, the participants were asked to listen to the word and laughter pairs again and rate how funny they thought each word was.

Each participant would hear the same word and laughter pairs as they did previously in the scanner, but the order of the pairs was randomised. There were 200 trials in total, containing the same trials in GL and PL conditions. The 100 NE trials were excluded for the purpose of time-saving. Participants would rate the funniness of each word on a 7-point Likert scale (‘How funny was the word the way that Ben said it?’, 1 – Not funny at all, 4 - Neutral, 7 - Extremely funny). For each trial, participants had up to 6 seconds to give a rating. There was a short practice session before the real task to let participants become familiar with the structure of the task. The post-scan behavioural task lasted approximately 25 minutes. See Figure 6.2.

6.3.3 Data Analysis

6.3.3.1 Behavioural data analysis

All behavioural data were analysed with IBM SPSS Statistics 20 (SPSS Inc., Chicago, IL, USA) and RStudio Team (2020).

6.3.3.1.1 Pre-scan behavioural: Implicit mentalising eye-tracking task

A Differential Looking Score (DLS) for each trial was calculated based on each participant’s Total Fixation Duration (TFD) of Areas of Interest (AOIs) which was automatically recorded by Tobii software.

The AOIs were activated and recorded when the audio-visual cue was displayed in each trial. The AOIs were categorised into three types: Correct (Belief Congruent); Incorrect (Belief Incongruent); and Head (Direction of the actress’s head) (See Figure 6.3). However, we were only interested in the Correct and Incorrect conditions in the following analysis. As we would expect the participant to look depending if they had or had not understood the task and whether they were able to implicitly mentalise by predicting the agent's next movement, indicated by anticipatory gaze movement, in alignment with the actress's false or true belief. The Total Fixation Duration (TFD) of the AOIs was automatically recorded by Tobii.

Subsequently, the DLS for each trial was calculated according to the formula used by Senju et al. (2009): the DLS for each trial was calculated by subtracting the Total Fixation Duration of the Incorrect region from the Total Fixation Duration of the Correct Region, divided by the sum of the Correct and Incorrect Fixation Duration. This would result in a score between -1 and 1: a score closer to 1 would indicate there was a greater proportion of tracked eye data fixated towards the correct AOI, and a score closer to -1 would indicate that all tracked eye data was fixated towards the incorrect AOI.

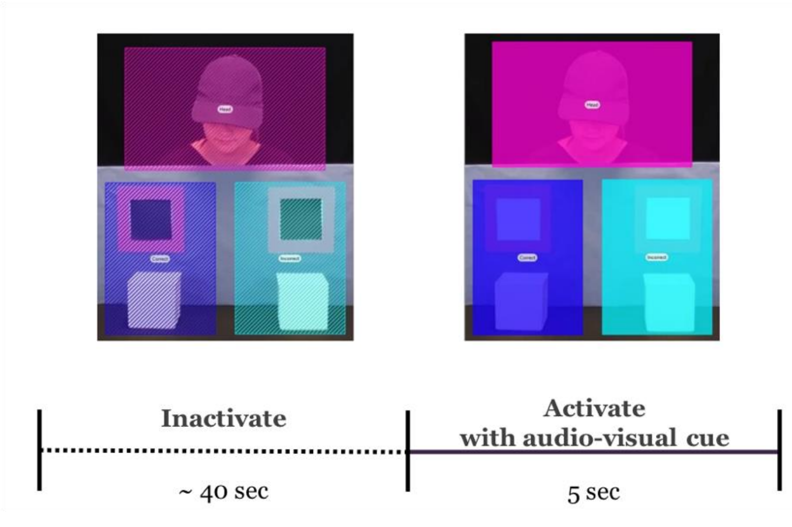


Figure 6.3 Selected frames showing Areas of Interest (AOIs).

Note. AOIs are inactive (translucent) until the audio-visual cue is played. pink = head direction, dark blue = incorrect/correct region, light blue = incorrect/correct region.

6.3.3.1.2 Post-scan behavioural: Implicit laughter rating

The current analysis is consistent with previous research investigating implicit laughter processing in Chapter 5. An item-based analysis was conducted; each word was treated as an item in the statistical analysis. This analysis was chosen as items were designed to produce a range of different funniness ratings. In this way, the effect of adding laughter to the funniness of each word could be assessed.

6.3.3.2 fMRI data analysis

Data were pre-processed and analysed in SPM12 (Wellcome Trust Centre for Neuroimaging, London, UK).

6.3.3.2.1 Pre-processing

The first three volumes were removed for each EPI sequence, to allow magnetisation to reach a dynamic equilibrium. The remaining volumes were first spatially aligned along the AC-PC axis for each participant. Secondly, the aligned images were slice time corrected using the last slice as a reference. Then, all slice timing corrected images were then spatially realigned and registered to mean. The structural image was co-registered with the mean of the slice time corrected images, and during segmentation, the structural scans were brought in line with SPM12 tissue probability maps. Forward deformations image from the segmentation step was then used to normalise the functional images to standard MNI space. Lastly, the normalised functional images were resampled into voxels of 2 × 2 x 2 mm and spatially smoothed using an isotropic 8 mm full width at half maximum (FWHM) Gaussian kernel.

6.3.3.2.2 Implicit laughter processing

At the single-subject level, event onsets from all 5 conditions [Genuine Laughter (GL), Posed Laughter (PL), NE Stimuli (NE), Rest, Vigilance (VIG)] were modelled as instantaneous and convolved with the canonical hemodynamic response function. Individual design matrices were constructed for each subject [All Laughs (GL & PL) >

Rest, All Laughs (GL & PL) > NE, GL > NE, PL > NE], modelling each of the three experimental conditions in four scanning runs and including movement parameters derived from the realignment step as nuisance variables. These contrast images were entered into a second level, two-sample t-tests for the group analysis (across groups). Results of the whole-brain analyses were corrected for multiple comparisons using a cluster-extent-based thresholding approach (Poline et al., 1997): a voxel-wise threshold of $p < 0.001$ was combined with a cluster extent threshold determined by SPM12 ($p < 0.05$ family-wise-error (FWE) cluster-corrected threshold). All clusters reported exceeded this cluster-corrected threshold. Reported cluster coordinates corresponded to the Montreal Neurological Institute (MNI) coordinate system and were labelled using the AAL labelling atlas in SPM12.

6.3.3.2.3 Implicit mentalising localiser

For each subject, the 2 conditions (TB and FB) were modelled as events of the duration of 45 seconds and convolved with the canonical hemodynamic response function. Second-level contrast images for TB > FB, and FB >TB was used to illustrate the overlap between perceptual responses to implicit processing of laughter and brain regions supporting implicit mentalising.

6.3.3.2.4 Region of Interest (ROIs)

For comparisons between groups, we conducted ROI analyses within regions for which we had a priori hypotheses based on previous fMRI experiments of nonverbal emotional vocalisations (McGettigan et al., 2015). Using the MarsBaR toolbox (Brett et al. 2002), spherical regions of interest (ROIs) of 8 mm radius were built around the peak voxels in selected contrasts and the beta values were extracted for the following analysis.

6.4 Results

6.4.1 Behavioural results

6.4.1.1 Pre-scan behavioural: Implicit mentalising eye-tracking task.

One NA participant was excluded from the following analysis because of the failure to record eye gaze due to technical issues. However, the groups (NA, n = 22; Autism, n = 25) remained comparable in demographic information. Firstly, one sample t-tests were conducted on the familiarisation trials in each group to examine whether their DLS scores differed from 0 (chance performance). If the familiarisation trials had been successful, we would expect a result that is significantly above chance which would indicate that the participants had understood the task. A significant difference from chance was found in the NA group, $t(21) = 28.821$, $p < .001$, $d = 6.166$. and a significant difference from chance was found in the autism group, $t(24) = 26.514$, $p < .001$, $d = 5.303$. Results in both groups were significantly above chance, indicating the contingency of events in the familiarisation trials had been established; participants in both groups had understood the task and the familiarisation trials were successful.

Secondly, one sample t-test was conducted on the experimental trials for each condition (FB/TB) in each group (NA/Autism) to examine whether the DLS scores would differ from chance. The NA group showed successful anticipatory gaze on the TB condition, $t(21) = 3.879$, $p < .001$, $d = .827$, and the results closely approached significance in the FB condition, $t(21) = 1.875$, $p = .075$, $d = .400$, suggesting that the NA group had appeared to understand the task overall and were able to show mentalising performance. The autism group showed successful anticipatory gaze in the TB condition, $t(24) = 3.084$, $p = .005 < .01$, $d = .617$, indicating that they had performed better than chance in the true belief condition. However, their performance in FB condition did not differ from chance, $t(24) = 1.392$, $p = .177$, $d = .278$, indicating that the autism group did not demonstrate successful anticipatory gaze, which is what we would have expected as the false trials are thought to elicit mentalising.

Finally, a 2 x 2 repeated measures analysis of variance (ANOVA) was conducted, including Belief (TB vs FB) as the within-subjects variable and Group (NA vs Autism) as the between-subjects variable. There was a significant main effect of Belief, $F[1,45] = 5.041$, $p = .030 < .05$, $\eta_p^2 = .101$, indicating that participants generally performed better in the TB condition ($M = .243$, $SD = .341$) than in the FB condition ($M = .119$, $SD = .347$). However, there was no significant main effect of Group, $F[1,45] = .433$, $p = .514$, $\eta_p^2 = .010$, indicating that the performance of the non-autistic group and autistic group are comparable. There was also no significant interaction effect between Belief and Group, $F[1,45] = .037$, $p = .84$, $\eta_p^2 = .001$, indicating that the performance of the non-autistic group and autistic group was not different from TB and FB conditions (See Figure 6.4).

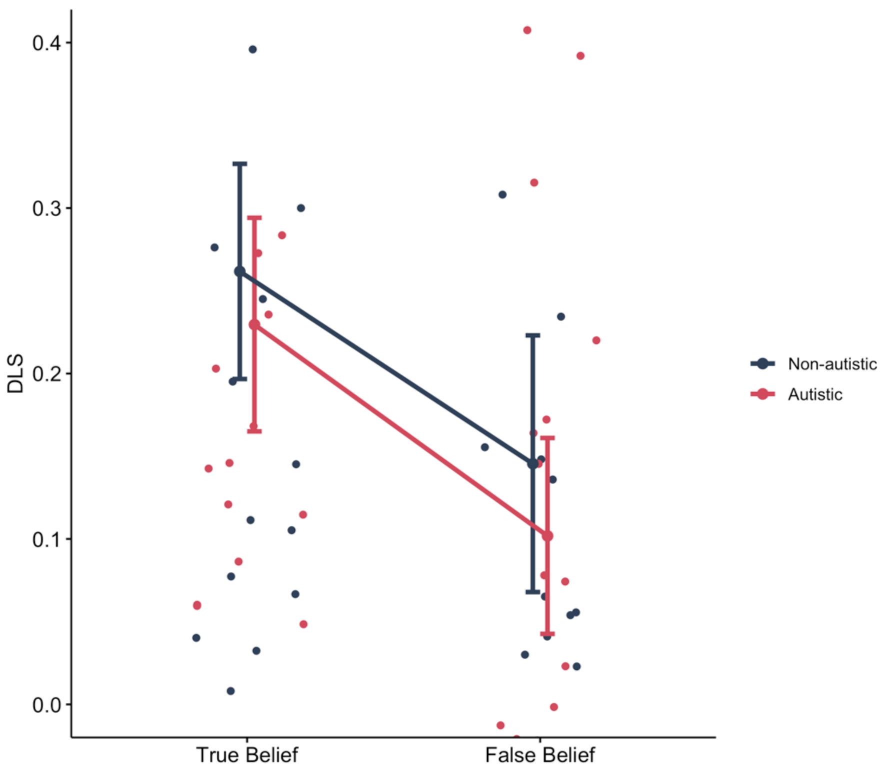


Figure 6.4 Performance of implicit mentalising in autistic and non-autistic groups

Note. The line plot revealed the average DLS scores in the true belief (TB) and false belief (FB) conditions in autistic (Red line) and Non-autistic groups (Blue line). Error bars represent the standard error of the mean. Jitters represent individual mean DLSscorese in each condition.

6.4.1.2 Post-scan behavioural: Implicit laughter rating task

The baseline ratings of words were pre-collected from a separate NA group (n = 58; see Method section), combined with data from the post-scan laughter task (NA; n = 25). Firstly, a paired samples t-test was conducted between the baseline sample and NA group, and the results showed that words with laughter (collapsed across genuine and posed laughter) (M = 3.416, SD = .578) were rated significantly funnier than words without laughter (M = 3.309, SD = .586, $t(299)$ = 3.473, p < .001 two-tailed, d = .201).

Secondly, a one-way repeated measure analysis of variance (ANOVA) was conducted as the Type of words (baseline vs genuine vs posed laughter) was the within-subject factor to evaluate the laughter modulation effect on the perceived funniness of words among the NA population. Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, $\chi^2(2) = .945$, $p < .001$. Therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .948$). There was a significant main effect of Type, $F[1.896,567.026] = 6.541$, $p = .002 < .01$ two-tailed, $\eta_p^2 = .021$, indicating that the NA rated the funniness of words significantly differed between different types of word stimuli. Post hoc analysis with a Bonferroni adjustment revealed that the perceived funniness of words stimuli was significantly increased from baseline ratings of words ($M = 3.309$, $SD = .586$) to words with genuine laughter ($M = 3.456$, $SD = .716$, $p < .001$ one tailed), and significantly increased from the ratings of words paired with posed laughter to words paired with genuine laughter ($p = .027$ one tailed). However, the baseline ratings of words were comparable with the ratings of words paired with posed laughter ($M = 3.368$, $SD = .678$, $p = .062$ one tailed). The significance level ($p < .1$ one tailed) was adjusted using Bonferroni correction for 3 comparisons (adjusted $p = .033$).

Regarding the results on matched samples, a 2 x 2 repeated measures analysis of variance (ANOVA) was conducted. As each word was treated as an item, therefore Group (NA vs autism) and Type of words (genuine vs posed laughter) were included as within-subject factors. There was a significant main effect of Group, $F[1,299] = 74.562$, $p < .001$, $\eta_p^2 = .200$, indicating that the non-autistic participants ($M = 3.412$, $SEM = .033$) rated all the types of word stimuli significantly funnier than the participants in autistic participants ($M = 3.151$, $SEM = .028$). There was a borderline significant main effect of Type of words, $F[1,299] = 3.770$, $p = .053$, $\eta_p^2 = .012$, following pairwise comparisons with Bonferroni correction indicating that words with genuine laughter (*M*

= 3.313, *SEM* = .031) were rated as significantly funnier than words with posed laughter (*M* = 3.250, *SEM* = .032; *p* = .027 < .05 one tailed) across all the participants. However, there was no interaction effect between Type and Group, *F*[1,299] = .410, *p* = .522, η_p^2 = .001, indicating that the non-autistic group and autistic group are comparable in the perceived funniness of words when paired with different types of laughter (See Figure 6.5).

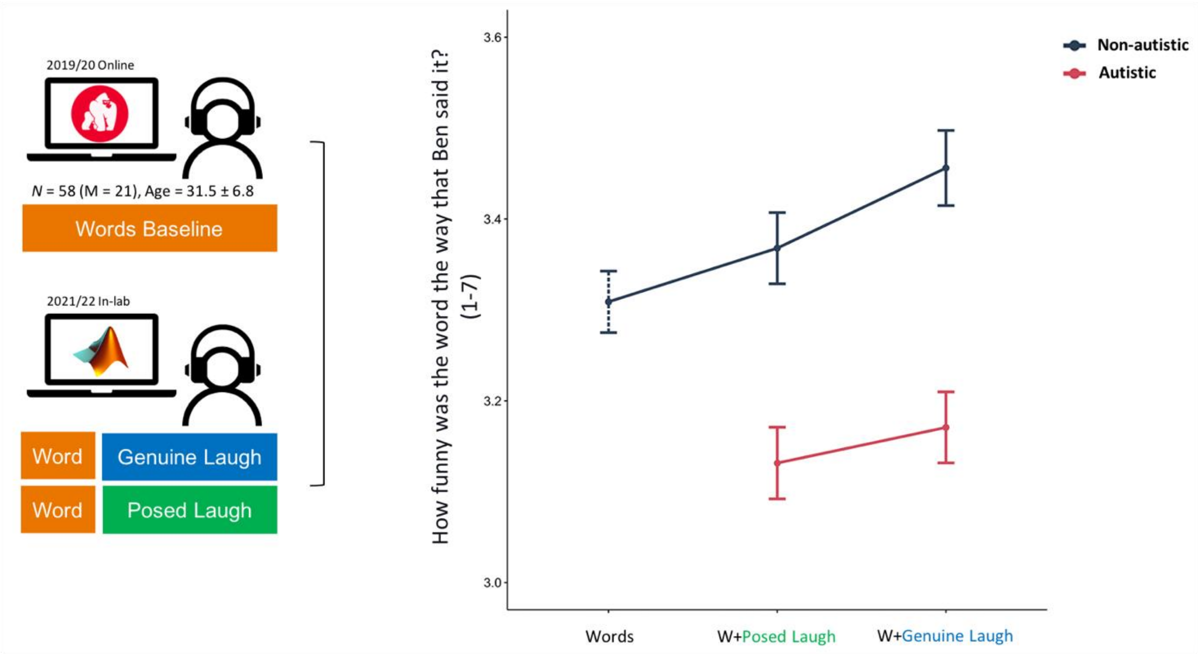


Figure 6.5 Implicit laughter processing of words

Note. The line plot reveals the pattern of laughter modulation effect on the perceived funniness of words. Including the pre-collected baseline ratings of words from a separate NA group (Dotted blue line), and the post-scan behavioural results when the words paired with posed laughter, and when paired with genuine laughter from the NA group (Blue line) and autism group (Red line). Error bars represent the standard error of the mean.

6.4.2 Whole brain results

6.4.2.1 The brain activation pattern in the implicit processing of Laughter across all participants

In order to explore which areas were involved in the implicit processing of laughter, we compared the activations which were activated in the passive listening condition to genuine and posed laughter against the rest conditions. Whole-brain analyses of responses to implicit processing of genuine and posed across all participants revealed activity across bilateral Heschl's gyrus (HG) and bilateral superior temporal gyrus (STG) (See Table 6-2; Figure. 6.6 A).

Table 6-2 Brain regions showing significant activity for the implicit processing of two types of laughter collapsed across two groups

Contrast	No. of voxels	Region	Coordinates			T	Z
			x	y	z		
All Laugh > Rest	45208	Left Heschl's gyrus	-44	-20	6	20.62	> 8
			-38	-28	14	20.14	> 8
		Left superior temporal gyrus	-54	-30	10	16.38	> 8
			-64	-26	4	16.20	> 8
			-60	-38	12	15.97	> 8
			-54	-8	-2	15.72	> 8
		Right Heschl's gyrus	48	-14	6	18.36	> 8
			44	-24	12	17.23	> 8
		Right superior temporal gyrus	60	-12	4	18.56	> 8
			66	-12	-2	18.52	> 8
			54	-24	6	18.32	> 8
			46	-22	0	18.20	> 8
			60	-4	-8	17.71	> 8
			58	0	-6	17.67	> 8
			64	-22	6	17.67	> 8
			48	-24	12	17.28	> 8

6.4.2.2 The brain activation pattern in the implicit processing in Laughter compared to NE stimuli across all participants

In order to explore which areas were involved in the implicit processing of laughter versus NE sound stimuli, we compared the activations which were activated in the passive listening condition to genuine and posed laughter against the NE condition. Whole-brain analyses of responses to implicit processing of genuine and posed versus NE sound stimuli across all participants revealed activity across bilateral Heschl's gyrus (HG), bilateral superior temporal gyrus (STG), bilateral supplementary motor area (SMA), bilateral posterior (PCC), mid (MCC) and anterior (ACC) cingulate cortex, bilateral precuneus, left middle temporal gyrus (MTG), and left medial frontal gyrus (mPFC). (See Table 6-3; Figure 6.6 B).

Table 6-3 Brain regions showed significant activity for the implicit processing of two types of laughter than the NE sound stimuli, which collapsed across two groups

Contrast	No. of voxels	Region	Coordinates			*T*	*Z*
			x	*y*	*z*		
All Laugh > NE	30686	Left Heschl's gyrus	-36	-28	14	20.80	> 8
			-44	-24	8	19.68	> 8
		/Left superior temporal gyrus	-44	-24	8	19.69	> 8
			-56	-14	6	17.17	> 8
			-56	-28	6	15.42	> 8
		/Left middle temporal gyrus	-66	-26	4	15.63	> 8
		/Right Heschl's gyrus	48	-14	4	18.29	> 8
			46	-24	10	16.62	> 8
		/Right superior temporal gyrus	60	-12	4	18.86	> 8
			52	-26	6	17.96	> 8
			66	-22	8	16.43	> 8
	2642	Right supplementary motor area	2	8	64	7.07	5.75
		/Right middle cingulate cortex	6	12	44	6.21	5.24
			6	22	34	5.92	5.05
		/Left supplementary motor area	-4	14	54	6.33	5.31
		/Left middle cingulate cortex	-6	14	40	6.01	5.11
		/Left anterior cingulate cortex	-6	26	22	5.64	4.87
			0	24	30	5.14	4.52
		/Left superior medial gyrus	-8	18	40	5.87	5.02
	833	Left precuneus	-10	-48	42	5.96	5.08
		/Left posterior cingulate cortex	-4	-38	30	4.16	3.80
		/Right precuneus	2	-48	38	4.97	4.33
		/Right posterior cingulate cortex	4	-38	28	3.92	3.61
	236	Left middle cingulate cortex	-8	-12	40	4.80	4.28
		/Right middle cingulate cortex	4	-8	36	3.95	3.63

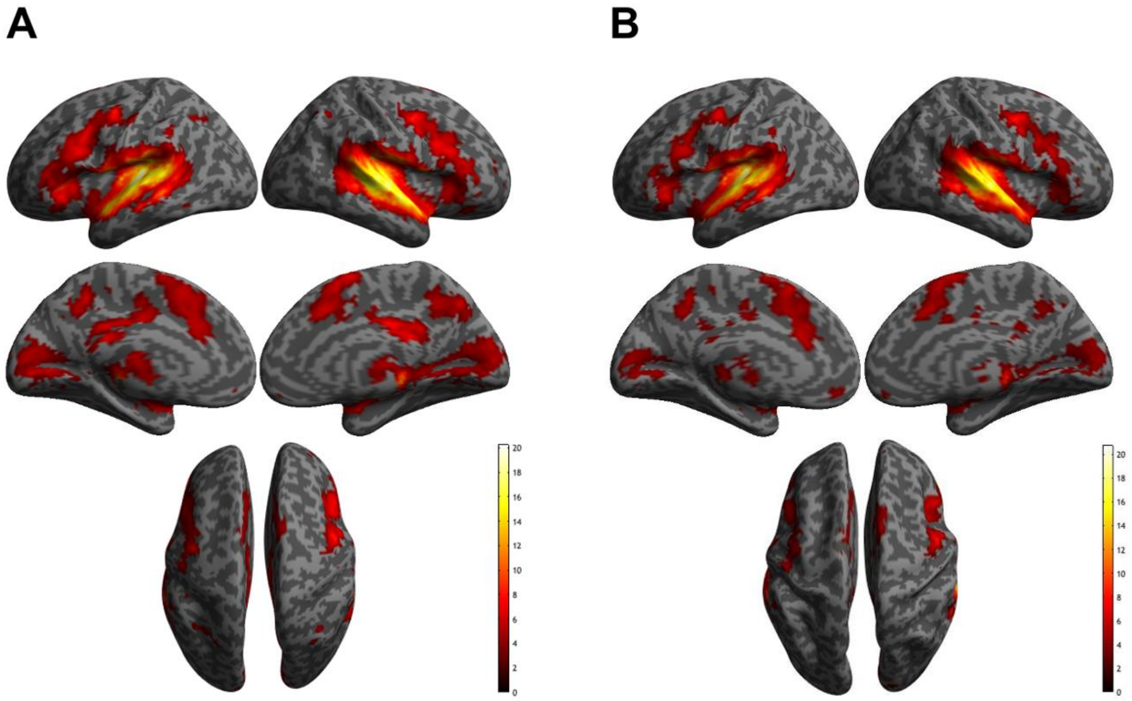


Figure 6.6 Activations of implicit processing (A) laughter; and (B) laughter versus NE sound stimuli across all participants

6.4.2.3 The brain activation pattern in the implicit processing in Genuine laughter compared to NE stimuli across all participants

In order to explore which areas were involved in the implicit processing of genuine laughter versus NE sound stimuli, we compared the activations which were activated in the passive listening condition to genuine laughter against the NE condition. Whole-brain analyses of responses to implicit processing of genuine laughter versus NE sound stimuli across all participants revealed activity across bilateral superior temporal gyrus (STG) (See Table 6-4; Figure 6.7 C).

Table 6-4 Brain regions showing significant activity for the implicit processing of genuine laughter than NE sound stimuli collapsed across two groups.

Contrast	No. of voxels	Region	Coordinates			T	Z
			x	y	z		
Genuine Laugh > NE	1030	Left superior temporal gyrus	-58	-14	2	7.50	5.99
			-58	-22	4	7.15	5.79
			-32	-30	16	5.45	4.74
			-42	-18	4	5.33	4.66
			-34	-26	10	5.22	4.58
			-34	-22	24	3.32	3.12
	1397	Right superior temporal gyrus	64	-10	4	8.15	6.33
			60	-10	2	8.12	6.32
			62	-4	2	7.96	6.23
			68	-16	4	7.76	6.13
			46	-26	4	5.44	4.73
			44	-30	12	5.38	4.69
			56	-28	4	5.37	4.69
			34	-26	16	5.21	4.57

6.4.2.4 The brain activation pattern in the implicit processing in Posed laughter compared to NE stimuli across all participants

In order to explore which areas were involved in the implicit processing of posed laughter versus NE sound stimuli, we compared the activations which were activated in the passive listening condition to posed laughter against the NE condition. Whole-brain analyses of responses to implicit processing of posed laughter versus NE sound stimuli across all participants revealed activity across bilateral superior temporal gyrus (STG), bilateral medial frontal gyrus (mPFC), left anterior cingulate cortex (ACC), left medial orbitofrontal cortex (mOFC), right superior frontal gyrus (SFG). (See Table 6-5; Figure 6.7 D).

Table 6-5 Brain regions showing significant activity for the implicit processing of posed laughter than NE sound stimuli collapsed across two groups

Contrast	No. of voxels	Region	Coordinates			*T*	*Z*
			x	*y*	*z*		
Posed Laugh > NE	1812	Left superior temporal gyrus	-56	-12	4	11.25	7.68
			-34	-26	16	8.84	6.67
			-44	-22	4	8.78	6.64
	165	Left anterior cingulate cortex	-12	42	4	4.01	3.68
			-10	42	-4	3.68	3.42
		/Left superior medial gyrus	-4	52	6	3.77	3.49
		/Left medial orbitofrontal cortex	-4	46	-14	3.65	3.39
			-8	46	-10	3.49	3.26
	2064	Right superior temporal gyrus	64	-10	4	10.97	7.57
			36	-26	16	7.47	5.97
			44	-18	6	7.22	5.83
	234	Right superior frontal gyrus	16	26	60	5.06	4.47
			16	12	50	4.72	4.42
			18	28	52	3.92	3.61
	290	Right superior frontal gyrus	18	54	38	4.57	4.11
			16	48	46	4.17	3.81
		/Right superior medial gyrus	6	54	34	3.43	3.21

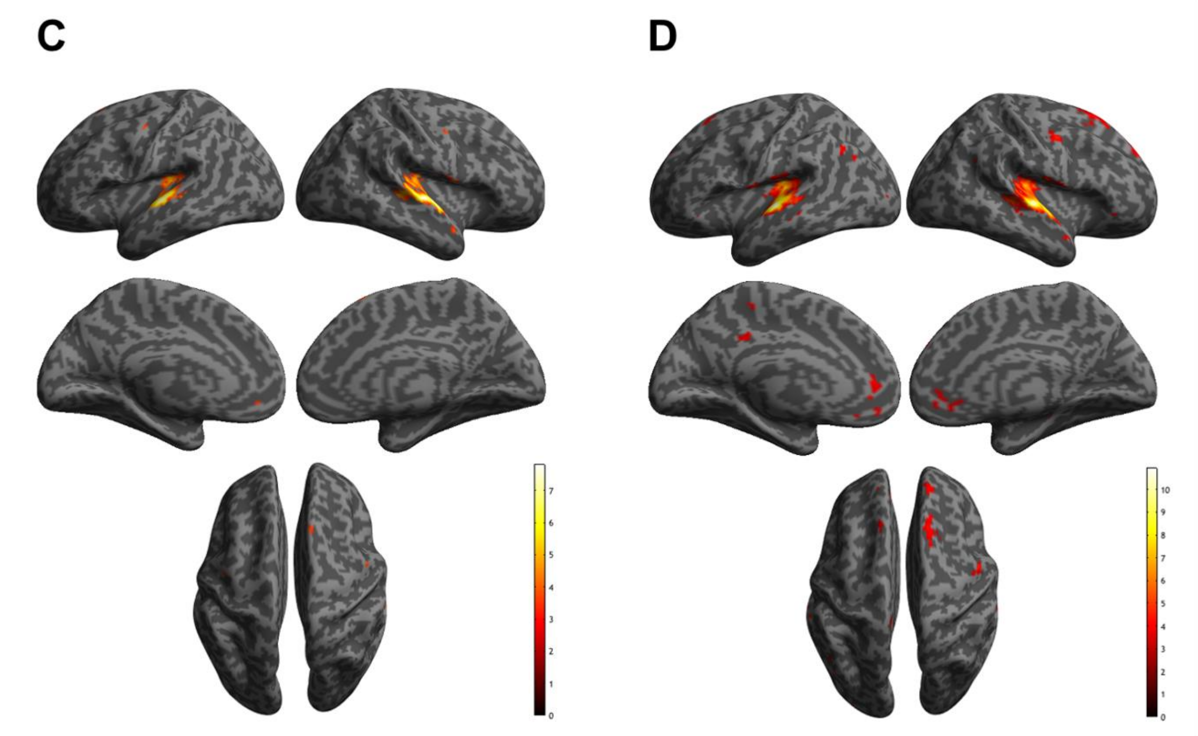


Figure 6.7 Activations of implicit processing of (C) genuine laughter versus NE sound stimuli; and implicit processing of (D) posed laughter versus NE sound stimuli across all participants

6.4.3 ROI results

We used a region of interest (ROI) approach to compare the difference in brain activation in perceptual conditions (GL > NE; PL > NE) between the two groups.

We did not detect any meaningful results from the implicit mentalising localiser, and no cluster survived from the whole brain analysis under the significance threshold (p < .001 uncorrected with p < .05 FWE corrected at cluster level). This may be due to the TB and FB videos only being present one time during the scan, and thus the signal was not strong enough to detect any activation in line with our prior hypotheses (mPFC area) under the current sample size. Since significant brain activations in the medial prefrontal cortex (mPFC; BA 10) was found in whole brain results of All laughter > NE and Posed laughter > NE. Therefore, we used the MNI peak coordinate (x = -3, y = 54, z = 9) from the previous fMRI study of the perception of posed laughter vs genuine laughter in neurotypical adults (McGettigan et al., 2015) with 8 mm sphere for the following analysis.

A 2 (Condition) x 2 (Group) ANOVA was conducted. There was a significant interaction effect between Condition and Group, F[1,44] = 7.111, p = .011 < .05, η_p^2 = .139, indicating that the brain activation of GL > NE and PL > NE was different from autistic and non-autistic participants. However, there was no significant main effect of Condition, F[1,44] = 2.087, p = .156, η_p^2 = .045, and significant main effect of Group, F[1,44] = .067, p = .797, η_p^2 = .002. Post hoc analyses revealed a significant difference between two perceptual conditions in the NA group, F[1,22] = 9.720, p = .005 < .01,

η_p^2 = .306 (GL > NE: *M* = .162, *SD* = 1.103; PL > NE: *M* = 1.048, *SD* = 1.120). However, there was no significant difference between perceptual conditions in the autistic group, *F*[1,22] = .661, *p* = .425, η_p^2 = .029 (GL > NE: *M* = .637, *SD* = 1.709; PL > NE: *M* = .374, *SD* = 1.903) (See Figure 6.8).

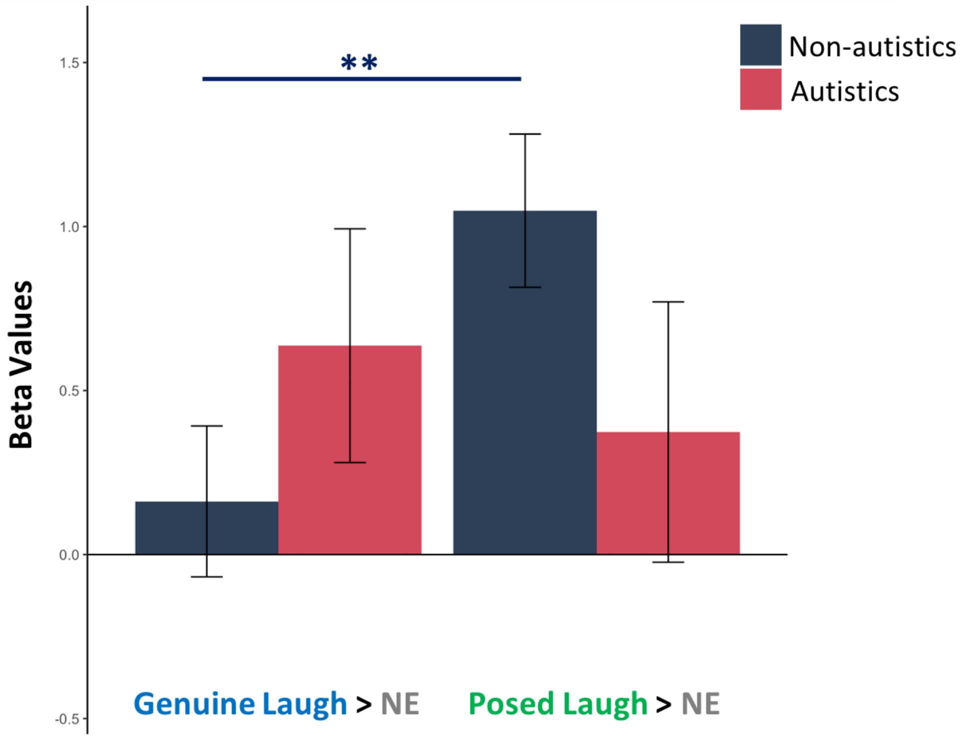


Figure 6.8 Brain activation in perceptual conditions (GL > NE; PL > NE) between the two groups

Note. Extracted beta values for the ROI with coordinates (-3, 54, 9), displayed in two perceptual conditions: Genuine laugh versus NE baseline and Posed laugh versus NE baseline. NE = Non-emotional and non-contagion baseline sound. Blue = Non-autistic group (NA). Red = Autistic group. Error bars represent the standard error of the mean.

6.5 Discussion and Conclusion

In summary, the current study implemented fMRI to investigate the underlying neural mechanism of the implicit processing of laughter, and how it relates to mentalising ability. In line with our prior hypothesis, we found that non-autistic participants showed greater activation in the medial prefrontal cortex (mPFC) during implicit processing of posed laughter than genuine laughter. However, no such difference has been found in autistic adults. At the behavioural level, we also found lower discrimination between these laughter types in autistic adults' relatives to non-autistic adults. Together, these findings illustrate the critical role of the medial prefrontal cortex and sensorimotor cortex play in the implicit processing of laughter, especially the engagement of mentalising ability in discriminating the laughter under different volitional control (e.g., genuine and posed laughter).

6.5.1 Implicit processing of laughter

In general, we found consistent activation in the auditory cortex, including bilateral Heschl's gyrus (HG) and bilateral superior temporal gyrus (STG) in the whole brain analysis across all participants from all four contrasts. The same profile is identified in previous studies about neurotypical participants' passive listening to genuine and posed laughter (Lavan et al., 2017; McGettigan et al., 2015; O'Nions et al., 2017; Szameitat et al., 2010). In addition, our finding of brain responses in the superior temporal cortex (including HG and STG) are consistent with previous studies of the perception of non-verbal emotional vocalisations, such as crying and screams (Fecteau et al., 2007; Sander et al., 2005), indicating the processing of emotional intensity of vocalisation recruited in these areas (Lavan et al., 2017).

Neural responses to laughter versus NE baseline are found in the bilateral cingulate cortex, supplementary motor area (SMA) and left medial frontal gyrus. This finding suggests the nature of perceiving laughter and noise-vocoded human vocalisation (NE stimuli) are different. This could be because participants are ready to join in the laughter while hearing the sound of laughter since laughter is highly contagious, and hearing the sound of laughter could easily elicit others' laughter(Provine, 1992). For instance, Warren et al. (2006) found hearing laughter and positive emotional vocalisation (e.g., cheers of triumph) engaged parts of the sensorimotor system, which overlapped with the production of smiling and laughing. Thus he proposed a sound-to-action response to emotional vocalisations. An alternative function role of the sensorimotor cortex is proposed by McGettigan et al. (2015), it acts as part of a stimulation mechanism for social understanding. Concretely, the automatic recruitment of the sensorimotor cortex while listening to laughter is associated with the emotional interpretation and understanding of laughter sound, especially distinguishing authentic mirthful (genuine) laughter from deliberate, acted (posed) laughs. Obviously, the engagement in sensorimotor system was reduced/absent in the processing of NE sound stimuli as it is non-emotional and non-contagious compared with laughter.

Again, the activation of the bilateral superior temporal gyrus (STG) was found in the implicit processing of genuine laughter versus NE sound and posed laughter versus NE sound, which is in line with previous findings of laughter perception. It is worth noticing that the design of the current task is different from previous laughter research(McGettigan et al., 2015; O'Nions et al., 2017). Instead of letting participants passively listen to laughter stimuli, we used an implicit measure of laughter processing and created a cover story about people's responses to a comedian telling funny words. Interestingly, we only found the activation of bilateral medial frontal gyrus (mPFC), left anterior cingulate cortex (ACC), left medial orbitofrontal cortex (mOFC) and right superior frontal gyrus (SFG) in implicitly processing posed laughter compared with NE baseline sound. The obligatory engagement of the sensorimotor system (e.g., ACC in our case) in implicit laughter processing of posed laughter further supports McGettigan et al. (2015)'s proposal of its functional role in discriminating laughter sound rather than a sound-to-action response to laughter. Otherwise, we should observe the same activation in the implicit processing of genuine laughter as well.

Interestingly, a previous study of humour perception presented participants with funny and non-funny cartoons and explicitly asked them to respond with a press of a button if they found the cartoon funny. Mobbs et al. (2003) found the intensity of the humourful experience was significantly correlated with activation in regions including pre-SMA, SMA, and anterior cingulate. The author relates pre-SMA, and SMA to the outward production of laughter, but also suggests that it could, in conjunction with the dorsal anterior cingulate cortex, be involved in a dopaminergic reward network associated with humour appreciation (Mobbs et al., 2003). Although humourful experience is subjective, however in the current experiment, the subjective humourful experience should be greater when the funny words are paired with genuine laughter in comparison with posed laughter; this has also been proven by post-scan behavioural ratings. Therefore, we should expect stronger activation in these regions during processing genuine laughter than posed laughter. Strikingly, we only detected some of the regions (SMA, anterior cingulate cortex) engaged in the implicit processing of posed laughter but in the absence of implicit processing of genuine laughter. Therefore, our finding provides another angle of the perception of humour and laughter; the function in these regions might predominantly reflect an automatic process of decoding social-emotional aspects of intentions in the current contexts (why this person deliberately laughs after the comedian's funny words). However, it is less likely to reflect motor aspects of expressive laughter involved in subjective humour appreciation.

Besides the recurring involvement of ACC, we also found activation in PFC during implicit processing posed laughter, especially the involvement of mPFC and mOFC, which overlap and belongs to the ventromedial prefrontal cortex. Mitchell (2006) observed a double dissociation of the brain mentalising regions: thinking about a similar other engaged a region of ventral mPFC (anterior rostral MFC), while thinking about a dissimilar other was associated with activity in a more dorsal region of mPFC (posterior rostral MFC) (brain regions taken from a review by Frith & Frith, 2006). Therefore, an alternative explanation is that hearing other people's posed laughter involved in social-cognitive/self-referential processing: participants automatically infer the mental states of others, thinking about how similar another person is perceived to be to me, and interestingly they are likely to think the other person who is laughing as a similar one rather a dissimilar under this context.

6.5.2 Group difference in implicit processing of laughter

In the following group comparison, the ROI analysis demonstrated that during passive implicitly listening to posed laughter, the non-autistic group showed significantly increased activation in the mPFC area compared to genuine laughter. These results replicate the findings of McGettigan et al. (2015) with the non-autistic group passive listening to posed (emitted) than genuine (evoked) laughter. In contrast, the autism group did not show a significant difference in activation between the two types of laughter.

In this implicit processing paradigm, we added funny words before two types of laughter to create a social context for the presence of laughter. Brain responses to passive listening of posed laughter in non-autistic adults support the hypothesis that increased demand for mentalising processes results in increased activation in the mPFC area during the processing of posed and conversational laughter. A previous study identified greater activation of mPFC (including anterior cingulate cortex) and precuneus during listening to social complex laughter (e.g., taunting, joyful) compared with tickling laughter without social meaning (Szameitat et al. 2010). Sumiya et al. (2017) also found greater activation in the mPFC while neurotypical participants heard group laughter versus single laughter in a socially rewarding context. We identify a similar profile of activations; however, it was possible that this response has reflected the social-emotional ambiguity of hearing laughter in this context (Lavan et al., 2017; McGettigan et al., 2015), suggesting the need for non-autistic adults to resolve the cause of this behaviour (e.g., another person laugh in this case), specifically, interpreting the meaning and intention behind the posed and communicative laughter followed with funny words.

Experimental evidence from neurophysiological studies found the medial prefrontal cortex contributes to the ability to mentalise, and as part of the brain's mentalising system, this region engages in processing the intentions of others (Frith, 2001). Therefore, the difference of activation in the mPFC area during implicitly processing these two types of laughter in autistic adults could be explained by the previous findings about an abnormal function within this mentalising region(C. D. Frith & Frith, 2006; Gilbert et al., 2009; White et al., 2014), it also reflects their ‘capacity limits in mentalising’ as proposed by White et al. (2014) since we are using an implicit paradigm in investigating laughter processing. Results of the implicit laughter task in the current neuroimaging study, in combination with the findings of the post-scan behavioural study, would provide a complete interpretation. Mentalizing ability is a relatively high-level cognitive process on its own (Amodio & Frith, 2006). In this paradigm, participants are not only involved in the process of auditory perception of acoustic features (i.e., pitch) and affective properties (i.e., intensity, arousal) of laughter but also use high-level social cognitive processing to understand the social-emotional context. In the post-scan laughter rating task, we found a significantly increasing effect of laughter modulation on funny words in non-autistic adults. However, such laughter modulation effect is lower in autistic adults. Although we found a borderline significance of Type of word stimuli (p = .053), it is worth noticing that this effect is driven by the ratings from non-autistic adults. This finding is partially in line with our previous laughter modulation effect on humorous stimuli in Chapter 5: in non-autistic adults, the addition of laughter increased the funniness of humour stimuli perceived to be; and they also found the humour stimuli funnier when paired with genuine than posed laughter. However, this effect was not consistently found in autistic adults. Additionally, non-autistic rated all types of words stimuli as funnier than autistic adults in the current task, we found the opposite in the jokes study (Cai et al., 2019) as autistic adults already have the concept that people laugh at jokes, they would find it normal and natural when there is laughter followed, even if they don't get the jokes, but they tend to give a higher rating. However, it is obvious that they do not get the humourless funny words as non-autistic adults, even when it is followed by laughter. In general, our finding suggests that autistic people can discriminate the authenticity of laughter, and are susceptible to the laughter modulation effects as non-autistic adults, though a smaller effect was detected in the current behavioural result. However, since we did not find any difference in implicit processing of two laughter types in the autism group in the ROI analysis, it is likely that non-autistic adults rely on the difference of acoustic features or affective properties of laughter rather than using a high-level of cognitive process, mentalising ability, to determine the social intention and meaning behind the laughter. Due to mentalising difficulties among autistic people, they may not be able to spontaneously infer other's mental states in social communication (posed and social laughter in this case), which is different from non-autistic adults.

6.5.3 Implicit mentalising processing

As previous fMRI studies have focused on the neural correlates of explicit mentalising processing by explicitly asking participants to be aware and respond to others' mental states (Saxe & Kanwisher, 2003). However, the activation of mPFC was not consistently found in such measures (Dodell-Feder et al., 2011; Overwalle & Baetens, 2009; Sommer et al., 2007). Therefore, we attempted to use an implicit mentalising task as a localiser to detect brain activation in the mPFC area. However, we did not detect any meaningful results from the implicit mentalising localiser in our preliminary analysis. This could be due to several reasons: A) participants only watched the TB and FB videos once while they were inside the scanner, the TB and FB conditions failed to repeat, and thus the signal was not strong enough to detect any activation, and B) our current sample size is not enough to detect a strong activation in line with prior hypothesis. It is worth noticing that a previous fMRI study investigated implicit false-belief processing by applying an explicit mentalising localiser. The author did not detect activation in the mPFC area but found activation in the temporal–parietal junction (TPJ) (Schneider et al., 2014). In the pre-scan behavioural task, we only found the main effect of Types of belief participants performed between TB and FB conditions, but we did not detect any group difference or interaction effect. Again, this may be because we have a relatively small sample size, and several of the participants were also diagnosed with ADD/ADHD, which could impact the data quality. In general, our finding highlights the need to adapt and develop a well-measured implicit mentalising task.

In conclusion, non-autistic adults showed greater activation in the medial prefrontal cortex (mPFC) during implicit processing of posed laughter versus genuine laughter. However, this difference was not found in autistic adults, and they also showed lower discrimination of these two types of laughter. Together, our findings suggest the medial prefrontal cortex and sensorimotor cortex are crucially involved in the implicit processing of laughter in social communication.

Chapter 7. General Discussion

In this thesis, through five studies, I investigated the question of whether there is any difference and how it differs in laughter behaviour between autistic and non-autistic adults. I first reviewed the deep evolutionary roots of laughter and indicated the social-emotional signature of genuine and posed laughter in social communication. Then based on the literature review of laughter research, especially the engagement of mentalizing ability in perceiving voluntary, posed laughter, I pointed out the need to understand laughter processing and production in the autistic population, and the importance of implementing multiple approaches to investigate the difference and implication from behavioural level to brain level. In Chapter 2, I investigated the difference in self-reported laughter experiences in everyday life between autistic and non-autistic adults. In chapter 3, I implemented a multi-level dyadic study of non-autistic and autistic pairs in a video recording and motion-capture setting to look at laughter production in friend and stranger pairs in different types of social situations. In Chapters 4, 5, and 6, I investigated the different patterns of laughter perception between autistic and non-autistic adults and highlighted the role of mentalizing ability in laughter processing by utilising explicit measure, implicit measure and fMRI. In this discussion, I will first summarize all the findings in each chapter, then discuss the implications and limitations of current research, as well as how these current results relate to previous studies and benefit future research.

7.1 A summary of the experimental chapters

In Chapter 2, as a first step, I intended to investigate the difference in daily laughter experience between autistic adults with IQ in the normal range and their non-autistic peers. Due to the likelihood of experimental settings influencing individuals' laughter behaviour in different ways, a self-reported questionnaire measure was used as it is more naturalistic and accurate in illustrating individuals' insights into their own social communication behaviour. A laughter questionnaire was applied to target four components, namely understanding, usage, liking and frequency, in individual daily laughter behaviour and experience. Through using independent t-tests analysed the results from an in-lab sample and a supplementary online sample, autistic adults reported that they laugh less (Frequency), enjoy laughter less (Liking) and find it more difficult to understand the social meaning of other people's laughter (Understanding) than non-autistic adults. However, autistic adults reported that they laugh on purpose as often as non-autistic adults (Usage), such as using intentional laughter to mediate social contexts. The result of this chapter indicated the difference in the personal experience of laughter behaviour between autistic and non-autistic: the difficulties in understanding the social meaning of others' laughter may result in autistic adults using and enjoying laughter less in everyday life, and may also indicate that autistic adults don't have a good insight into their own laughter as a social communicative tool and thus use different strategies to understand and produce laughter in social interactions.

In Chapter 3, I further investigated whether relationship closeness affects laughter production in autistic and non-autistic adults by implementing a multi-level dyadic study in a video recording setting. In particular, I look at laughter production in friend and stranger pairs in different types of social situations. 30 Mixed (autistic and non-autistic pairs) and 29 NA (non-autistic and non-autistic pairs) Strangers dyads and 7 Mixed and 12 NA Friends dyads were filmed while completing a naturalistic, unstructured conversational task and a funny video-watching task. Their laughter behaviour was extracted, quantified and annotated and thus the duration of Total, Shared and Unshared laughter were calculated the in each dyad. Regardless of the closeness of the relationship, Mixed dyads produced significantly less laughter than NA dyads in both the conversation task and the video-watching task. In addition, the relationship closeness only affects laughter production in NA dyads. NA dyads produced more laughter when interacting with their friend than with a stranger, whilst the amount of laughter in Mixed dyads did not differ when interacting with their friend or a stranger. These findings indicated that autistic adults show a different pattern of laughter production relative to non-autistic adults during social communication, more specifically, Mixed dyads generally used laughter less as a communicative signal during social interaction, and the amount of laughter they produced was less influenced by the closeness of the relationship. However, this result is also possible that a mismatch between autistic and non-autistic communication, specifically in existing friendships, may have resulted in patterns of laughter production more akin to that seen between strangers.

From Chapter 4, I switched to looking at the difference in laughter perception in autistic and non-autistic adults. In this chapter, an explicit rating task was applied to investigate the perceptual and affective properties of laughter and whether these features were influenced by the authenticity of laughter in both the autistic and non-autistic groups. Participants were asked to rate the authenticity, contagion, valence and arousal of a range of genuine and posed laughter samples. The results showed that both autistic and non-autistic adults were able to discriminate between genuine and posed laughter. However, a lesser degree of differentiation was found in non-autistic adults, they rated posed laughter as more authentic, more positive and causing more emotional arousal than their non-autistic peers did, and hence to be more similar to genuine laughter. This finding suggests that there are subtle perceptual differences between autistic and non-autistic adults in explicitly perceiving genuine and posed laughter and its affective properties.

Following up on the finding from explicit laughter processing in Chapter 4, I took a step forward to measure the implicit processing of genuine and posed laughter in Chapter 5. I created a novel implicit laughter task, by adding genuine or posed laughter to a variety of forms of humour stimuli including puns jokes, burps sounds and slapstick videos, and to see how it affects people's perceived funniness of humour stimuli to be via three datasets. Critically, the social and emotional meaning of laughter is being implicitly processed by people. In non-autistic adults, the addition of laughter increased the funniness of humour stimuli perceived to be; and they also found the humour stimuli funnier when paired with genuine than posed laughter. Interestingly, this effect was not consistently found in autistic adults: the same laughter modulation effect was found in jokes, however, adding laughter failed to modulate the funniness of burps and slapstick videos. This finding is further evidence that autistic adults with high IQs have a different pattern of implicit processing of laughter relative to non-autistic adults.

Following up on our findings in Chapter 4 and Chapter 5: difference pattern of laughter processing exits between autistic and non-autistic adults. In Chapter 6, I integrated fMRI to investigate the underlying neural mechanism of the implicit processing of laughter and how it relates to mentalizing ability. Autistic and non-autistic adults passively listened to funny words paired with genuine laughter, posed laughter or baseline stimuli (non-emotional non-contagious human vocalizations) inside the scanner. In the ROI analysis, greater activation in the medial prefrontal cortex (mPFC) was found in non-autistic adults during implicit processing of posed laughter versus genuine laughter, but not found in autistic adults. At the behavioural level, reduced discrimination between laughter types was found in autistic adults. Together, these findings illustrate the critical role of the medial prefrontal cortex and sensorimotor cortex play in the implicit processing of laughter, especially the engagement of mentalizing ability in implicitly processing the socio-emotional meaning of laughter and therefore discriminating the authenticity of laughter (e.g., genuine and posed laughter).

7.2 The difference in laughter behaviour in autistic and non-autistic adults

Human laughter is more than an uncontrolled and genuine emotional expression in response to humour and tickling, it predominately occurs in conversation: people laugh volitionally in the absence of humour and utilise laughter as a communicative signal to punctuate speech, show liking, agreement and affiliation to others (Provine, 1993, 2004; Vettin & Todt, 2004). Therefore, Gervais and Wilson (2005) argued for the distinction between ‘Duchenne’ laughter which is driven by external stimuli and ‘Non-Duchenne’ laughter which is under voluntary control. The nature of laughter as a social behaviour is crucial for us to establish and maintain social relationships (Scott et al., 2014). Furthermore, the deep evolutionary root of laughter led to the proposal that laughter promotes group cohesion and social bonding, as well as builds rapport in human interaction (R. I. M. Dunbar et al., 2012; Manninen et al., 2017). In the scope of this thesis, I followed the proposal of laughter as a social behaviour and hence further extend our current knowledge of laughter on three aspects: A) whether laughter behaviour differs between autistic and non-autistic adults; B) how does this difference is associated with the socio-emotional determinants of laughter; and C) whether this difference could be explained by the engagement of mentalizing ability in social communication.

In the exploratory questionnaire study, four components were designed to evaluate people’s daily laughter behaviour and experience: Frequency and Usage assessed people’s laughter behaviour at the production level, while Liking and Understanding assessed laughter behaviour at the perceptual level. Considering the salient social nature of laughter, it is not surprising that autistic adults reported that they less enjoy hearing other's laughter (Liking) and have difficulty in understanding the social meaning of other's laughter (Understanding), because they struggle in social communication, in this case, they may find it difficultly to understand and the intention and mental state of other's laughter due to mentalizing difficulty. In addition, they reported a lower frequency of laughing (Frequency) than non-autistic adults, this could be because they more often laugh in response to a positive internal state but less produce laughter serving as a social and communicative signal. However, non-autistic and autistic adults reported that they use laughter for its positive social effects (Usage) to the same degree. This finding could indicate a different pattern of self-reported everyday laughter behaviour in autistic and non-autistic adults. However, the quality of the self-reported questionnaire is related to individual self-awareness and also somehow affects by reputation management, additionally, autistic adults employ strategies and behaviour to cope with the non-autistic social world, and only a small number of them are aware of their social camouflaging (Cook et al., 2021; Mandy, 2019). Therefore, this finding might also reflect a less good insight into their own laughter in autistic adults.

To gain more insights into the difference in laughter production between autistic and non-autistic adults during real-world social interaction, I designed a multilevel dyadic study by manipulating the relationship closeness in NA dyads and Mixed dyads and to see how it affects their laughter production in different types of social situation (shared conversation vs shared funny video watching). Our results showed that NA Friends produced significantly more unshared and shared laughter than NA Strangers in both social situations, which is in line with previous findings that neurotypical friends and romantic partners showed longer laughter duration during interaction (KURTZ & ALGOE, 2015; Smoski & Bachorowski, 2003) This further supported that laughter is a social behaviour strongly mediated by social contexts, people laugh more often when interacting with familiar people, and hence laughter is an indication of relational closeness and affiliation (KURTZ & ALGOE, 2015; Kurtz & Algoe, 2017; Scott et al., 2014). In contrast, the amount of laughter produced by Mixed dyads is comparable in Friends and Strangers no matter in conversation or video-watching. The absence of an effect of relationship closeness in Mixed dyads could be explained by the existence of a different pattern of laughter production in autistic adults. Previous studies found a quantitative and qualitative difference in laughter production between autistic children and typical developing children or children with Down Syndrome (Reddy et al., 2002). Autistic children showed a reduced frequency of presenting positive expressions and rarely laughed in response to social events (Reddy et al., 2002). Additionally, reduced contagious laughter has been found in autistic children (Helt et al., 2020; Helt & Fein, 2016a), they less join in others' laughter and less use laughter as an exchanging signal relative to their non-autistic peers (Bauminger et al., 2008; Helt & Fein, 2016a; Hudenko et al., 2009; Reddy et al., 2002). As research showed that the frequency of laughing together reflected the desire for further affiliation and relationship development in non-autistic adults (Kashdan et al., 2014b; Treger et al., 2013). Therefore, their non-autistic partners were probably less motivated to display pro-social behaviours such as laughter in Mixed dyads. Our findings indicated that autistic adults are likely to laugh in a different way relative to non-autistic adults in social communication, and it also reflects a mismatch between autistic and non-autistic communication. This tendency of using laughter less as a social signal could be autistic adults struggling with understanding the mental states and social intentions of other's laughter due to mentalizing difficulty. Consequently, failure in understanding others' laughter could lead to difficulties for them in replicating and using laughter as a social signal in interactions.

To evaluate whether autistic and non-autistic adults show a different profile in laughter processing, I implemented a series of laughter processing studies combining explicit measure, implicit measure and fMRI approaches to empirically test their perceptual difference of genuine and posed laughter from behavioural level to brain level. Both autistic and non-autistic adults were able to discriminate genuine and posed laughter during explicit rating of the perceptual and affective properties of laughter: genuine laughter was rated significantly more authentic, contagious, positive and emotionally arousing than posed laughter. This finding is consistent with previous evidence that genuine laughter is perceived as more authentic than posed laughter in neurotypical adults (McGettigan et al., 2015; Lavan et al, 2017; Chen, 2018), additionally, the authenticity of laughter affects people's perceptual judgement of its affective properties — genuine laughter was perceived as more intense, more arousing, more positive, and more emotional and behavioural contagious than posed laughter (Lavan et al., 2016, 2017; McGettigan et al., 2015). However, autistic adults rated posed laughter as more authentic, more positive and causing more emotional arousal than their non-autistic peers did, and hence to be more similar to genuine laughter. Furthermore, I examined this perceptual difference in socio-emotional meaning of laughter by applying a series of implicit laughter processing tasks based on the novel paradigm I designed, showing the addition of laughter modulated the funniness of a variety of humour stimuli (e.g., puns jokes, burp sounds, slapstick videos). This paradigm required participants to make a judgement of the funniness rating of humour stimuli in addition to laughter, in this way, the socio-emotional meaning of laughter would be implicitly processed by participants: participants would spontaneously attribute the mental state while hearing other's laughter and hence implicitly differentiate genuine and posed laughter in this process. In non-autistic adults, the addition of laughter increased the funniness of humour stimuli perceived to be; and they also found the humour stimuli funnier when paired with genuine than posed laughter, which is in line with previous findings that the presence of laughter not only enhanced individual perceived enjoyment and pleasure of humour stimuli (e.g. jokes, comedy, cartoons) (Helt & Fein, 2016a; Sumiya et al., 2017, 2020), but also the perceived intensity of laughter is strongly positive corrected with perceived humour (McKeown & W., 2016). This finding suggests that the social and emotional meaning of laughter is implicit processing by non-autistic adults, in addition, they cannot ignore the kind of laughter during the implicit processing process. Similar to the finding on explicit laughter processing, autistic adults with high IQs have a different pattern of implicit processing of laughter relative to non-autistic adults. Notably, the laughter modulation effect was not consistently found in autistic adults: the same laughter modulation effect was found in jokes, however, adding laughter failed to modulate the funniness of burps and slapstick videos. This pattern we observed in the current studies has also been found in previous studies: autistic children found cartoons with a laughter track less enjoyable compared with cartoons presented alone (Helt & Fein, 2016a) and show greater sensitivity to task context and familiarity of the laugher (Helt et al., 2020). In another study, autistic adults reported experiencing less pleasure when the visual jokes followed by group laughter compared to neurotypical adults (Sumiya et al., 2020).

From both explicit and implicit processing, we consistently find a different perceptual pattern exists between autistic and non-autistic adults. In general, autistic adults perform poorer in discriminating between genuine and posed laughter, this could be due to their difficulty in the understanding socio-emotional meaning of laughter. Interestingly, autistic adults have also been found performed less well in discriminating between Duchenne (genuine) and non-Duchenne (posed) smiles than their neurotypical (NT) peers (Boraston et al., 2008). Importantly, the author interpreted the ability to distinguish a real from a posed smile as associated with the ability in understanding and attribute other's mental state, as a posed smile can indicate the pretence of happiness or pleasure (Boraston et al., 2008).

Taking this evidence into consideration, I conducted a subsequent fMRI study to prove whether such difficulty in processing nonverbal social signals is associated with their limitation in mentalizing ability. I adapted the implicit laughter processing paradigm, autistic and non-autistic adults passively listened to funny words paired with genuine laughter, posed laughter or baseline stimuli (non-emotional non-contagious human vocalizations) inside the scanner. In the ROI analysis, non-autistic participants showed increased activation in the medial prefrontal cortex (mPFC) during implicit processing of posed laughter versus genuine laughter. However, no such difference was found in autistic adults, and they also showed reduced discrimination between these laughter types in the behavioural rating task. This result replicated previous findings from McGettigan et al. (2015) with greater activation in the mPFC found when neurotypical adults passive listening to posed (emitted) than genuine (evoked) laughter. Other studies used different forms of laughter stimuli also found the engagement of mPFC area in neurotypical adults while listening to social complex laughter (e.g., taunting, joyful) versus tickling laughter without social meaning (Szameitat et al., 2010; Wildgruber et al., 2013), and hearing 'group laughter' versus 'single laughter' in a socially rewarding context (Simuya et al., 2017). Simuya et al. (2020) further detect the social rewarding paradigm on autistic adults and found greater activation in arMPFC between groups (neurotypical > autism) while receiving 'single laughter' as a rewarding cue. Therefore, the similar profile we identified further evident that the social-emotional ambiguity of hearing laughter in this context (Lavan et al., 2017; McGettigan et al., 2015), suggesting non-autistic adults experience an obligatory attempt to determine/resolve the cause of this behaviour (e.g., another person laughs in this case), specifically, they engaged in a process in attributing and interpreting other's mental state behind the posed and communicative laughter. Overall, our findings indicate the medial prefrontal cortex and sensorimotor cortex to be crucially involved in the implicit processing of laughter, especially highlighting the engagement of the medial prefrontal cortex and mentalizing in the implicit processing of posed and communicative laughter.

In summary, autistic adults consistently observed a different pattern of laughter behaviour relative to their non-autistic peers. Through multiple research or analysis approaches, our studies shed light on understanding the difference in laughter behaviour between two populations and explore whether this difference is associated with the socio-emotional determinants of laughter, and further illustrate the critical role of mentalizing ability in non-verbal social communication.

7.3 Implications of the thesis

Most studies on social communication and interactions in autism have mainly focused on non-verbal visual cues, such as eye contact, gestures, and facial expressions in autistic individuals (Golarai et al., 2006; Senju et al., 2009; Senju & Johnson, 2009; Trevisan et al., 2018). Auditory cues have been largely neglected in this domain, with nonverbal vocalizations being under-researched. In this thesis, we shift our focus to laughter. As a universal positive nonverbal vocalization, laughter serves as a salient index for human social well-being and plays a critical role in establishing and maintaining social relationships during social communication (Provine, 1993; Provine & Fischer, 1989; Scott et al., 2014, 2022; Vettin & Todt, 2004). The unique role of laughter in maintaining social bonding makes it worthwhile to emphasize its research in the context of daily communication.

This thesis addressed this gap in research by investigating laughter as a nonverbal communicative signal in autistic adults who experience challenges in social communication. It deepened our understanding of laughter as a nonverbal communicative signal in the context of autism. In behavioural level, unique patterns of laughter perception and production were consistently found between autistic people and non-autistic people within their life experience and social communication. Additionally, this thesis expanded our knowledge about the underlying neural mechanism of laughter processing. Specifically, the fMRI study showed that the engagement of mPFC, likely due to its role in metalizing ability, is necessary for the processing of posed laughter in non-autistic adults but not in autistic adults. Combining evidence from both behavioural and brain levels, it has been found that autistic adults are able to differentiate between posed and genuine laughter in the behavioural level, although their ability may not as good as that of non-autistic adults. This indicates that they have multiple different processes that contribute to laughter processing, potentially through alternative, low-level cognitive processes. However, the differences in laughter production patterns and self-reported experiences also suggest the possibility of a mismatch in daily communication between autistic and non-autistic people from a neurodiversity perspective.

This thesis sheds light on the communicative function of laughter in the context of autism and aims to contribute to a better understanding of the challenges faced by autistic people in social communication. The use of laughter as a clinical practice to help autistic people is a complex and intriguing topic that warrants further exploration. While laughter is a crucial social signal in social boding and interaction, its effectiveness as a therapeutic tool autistic people remains unclear. Indeed, while laughter may be seen as simplistic or "primitive" for clinical practice and intervention, it may hold promise as a tool to help improve the social communication skills of autistic people. For example, society could encourage non-autistic people to be more patient, understanding, and to deliver clear communicative signals during social interactions with autistic people. As laughter can be a sign of enjoyment and openness to communication, encouraging reciprocal communication and building positive social connections between autistic and non-autistic individuals may also be helpful. For instance, helping autistic individuals improve their social communication skills in turn-taking, eye contact, or even using laughter in a reciprocal way during communication. Overall, improving social communication skills in autistic individuals is a complex process that requires a personalized and individualized approach. While laughter can be a useful tool, it should be used in conjunction with other interventions and with a focus on building connections and understanding the individual's unique needs and preferences. More importantly, the question of whether laughter can be a useful form of intervention and support for autistic people requires more research and discussion within the community.

7.4 Limitations of the current study and future directions

It is no doubt that laughter research is still in its infancy, and limited attention has focused on laughter behaviour in the autistic population. Notably, there are several limitations to the current thesis, which could give insights for further research.

Firstly, investigating laughter behaviour in experimental settings has its own methodology limitation. Although participants were given a cover story (e.g., a study about humour/social communication) in the testing, however, participants awarded they are video-recorded and their performance will be judged later, or they laid inside the scanner for a long time and tolerated with the noise created by scan sequence. Therefore, it is somehow inevitable to affect their performance and such has its shortage to reflect people's laughter behaviour in real life. It is worth considering a more ecological validity approach to examine laughter behaviour in the future.

Secondly, research on the clinical population (autistic adults in our case) is always challenging in having enough sample size. For instance, as I stated in Chapter 3, we were unable to establish a convincing profile of laughter production in autistic and autistic pairs since the sample size is too small (2 Friend pairs vs 4 Stranger pairs). Additionally, autism is a spectrum disorder because it is different for every autistic person, and our participants are autistic adults with high IQs, so they are very likely to be very good at social camouflaging no matter in research or in real life. Therefore, the individual difference also plays an important role in the data we collected. However, we mainly focused on the group-level difference in the current analysis. Future research is needed to enlarge the sample size and address the issue of individual difference and how camouflage and masking effect plays a role in laughter behaviour in autistic adults.

Thirdly, there are other aspects of laughter that are worth investigating in future research. Laughter has its unique contagion effect and is the only positive emotional vocalization showing this contagious-laughter effect. What is the physiological reason behind this? And does this effect necessary to be associated with humour? In the current thesis, we view laughter as a positive social signal which is important for social bonding. However, laughter can be nasty and contain negative meanings in social situations, for example, laughing at someone, sarcastic laughter. Laughter as a social glue is strongly influenced by one's in-group/out-group bias. Actually, laughter contains more social meaning and social functions as we know, and it is obvious that laughter has been under-researched.

Finally, it is important to understand the developmental trajectory of laughter behaviour, and laughter behaviour in other clinical populations. For example, people with neurological disease such as amyotrophic lateral sclerosis (ALS) shows uncontrollable pathological laughter (Thakore & Pioro, 2017). Human being gradually acquires the social usage of laughter through development and interaction. Understanding laughter in these domains will provide us with a full picture of human laughter across the lifespan.

7.5 Conclusion

In this thesis, I further extended our current understanding of laughter as a social signal from non-autistic adults to autistic adults. Through multiple approaches, I address the questions that whether laughter behaviour is different between autistic and non-autistic adults, whether this different profile is associated with the socio-emotional determinants of laughter; and whether this difference could be explained by the engagement of mentalizing ability in social communication. In general, different patterns of laughter behaviour were consistently observed between autistic and non-autistic adults. In an exploratory questionnaire study, autistic adults reported laughing less, enjoying laughter less and finding it more difficult to understand other people's laughter in everyday life. In a multi-level dyadic study, they showed a different pattern of laughter production relative to non-autistic adults in social communication: non-autistic pairs laughed more when interacting with their friend than a stranger, whilst the amount of laughter produced by pairs of one autistic and one non-autistic adult was not affected by the closeness of the relationship. Furthermore, autistic adults performed less well in discriminating genuine and posed laughter in both explicit and implicit processing. Through a follow-up fMRI study, it is evident the critical role of the medial prefrontal cortex and mentalizing ability involves processing the socio-emotional meaning of laughter, and hence results in autistic adults experiencing difficulties in attributing the mental state of other's laughter. Across five experiments, this thesis includes studies that implemented a series of novel research or analysis approaches to guarantee the results are robust. The current finding of a different profile of laughter behaviour in autistic adults offers a new direction to understand laughter as a socio-emotional vocalization and the involvement of mentalizing ability in non-verbal social communication, which shed light on future research orientation.

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